SCIENCE EDUCATION

GUYBERT PHILLIPS CAHOON

VOLUME 45 APRIL, 1961 NUMBER 3

#3

SCIENCE EDUCATION

THE OFFICIAL ORGAN OF

National Association for Research in Science Teaching
Council for Elementary Science International
Association on the Education of Teachers in Science

CLARENCE M. PRUITT, EDITOR
University of Tampa
Tampa, Florida

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GUYBERT PHILLIPS CAHOON

AT the suggestion of a number of his friends, the Twenty-Sixth Science Education Recognition Award is made to Dr. Guybert Phillips Cahoon. Dr. Cahoon was born in Minneiska, Minnesota, November 25, 1896. His parents were Guybert Alson Cahoon and Grace May Silvernail (deceased July 28, 1960). The father was a Methodist minister, and as a consequence the family lived in a number of different Minnesota communities. Dr. Cahoon's early schooling was received in several different places and schools, including Worthington, Minnesota. Both his father and his brother died when Dr. Cahoon was a young man. His mother remarried and when her second husband (Mr. Dean) died, she came to live with the Cahoons.

Dr. Cahoon married Lucille Smith in Berkeley, California, February 19, 1925. Three of the four Cahoon children were born in Berkeley, California and the fourth was born in Columbus, Ohio. The children are: Evelyn G. (Mrs. Tom Evans), 16 E. Como Avenue, Columbus, Ohio; G. David Cahoon, 55 W. Lane Avenue, Columbus, Ohio (presently working toward a Ph.D. degree at Ohio State University, majoring in Education (Social Studies and Guidance); Richard Alson Cahoon, 1334 West 3rd Avenue, Columbus, Ohio (also presently working toward a Ph.D degree in Psychology at Ohio State University); and Margaret A. (Mrs. E. S. Smith), 1519 Ambrose Street, Cincinnati, Ohio. Both daughters earned B.S. degrees at Ohio State University, Evelyn majoring in Education and Margaret in Sociology. The Cahoons have eight grandchildren: David L. Evans, Mary Kay Evans, William Lee Evans, James Guybert Evans, Laurie Ann Cahoon, Becky Sue Cahoon, Deborah Jean Cahoon, and Mark David Cahoon.

Dr. and Mrs. Cahoon have been active members of the Methodist Church.

Dr. Cahoon graduated from the Mankato High School, Mankato Minnesota. He received a B.S. degree from Hamline College, St. Paul, Minnesota, in 1920; M.A. (1929) and Ed.D. (1937) degrees from the University of California, Berkeley, California.

Teaching experience includes: Science and mathematics, Mankato High School, Mankato, Minnesota, 1920–21; Principal, Parker Junior College, Winnebago, Minnesota, 1921–23; science and critic teacher, La Crosse High School, La Crosse, Wisconsin, 1923–24; science teacher, Stockton High School, Stockton, California, 1924–25; supervising teacher in science, University High School, Oakland California, 1925–34; assistant professor, University School, Ohio State University, Columbus, Ohio, 1934–35; Associate professor and Professor (1942), Department of Education, Ohio State University, 1935 until his retirement in 1959 with the rank of Professor Emeritus. Dr. Cahoon was on leave of absence in 1942 to teach at the McGuffey School, Miami University, Oxford, Ohio. During most of World War II, he served as educational consultant for the Civil Aeronautics Administration. In this work he organized and participated in numerous aviation operations institutes. Dr. Cahoon was consultant in science edu-

cation for the U. S. Office of Education and was a member of the national advisory Committee for the Civil Air Patrol of the Army Air Forces. In 1946 he was a represeṅtive at the "World Congress on Air-Age Education" held in New York City. He also was a delegate to the 5th National Conference convened by the U. S. National Commission for UNESCO.

Publications include book reviews, contributions to yearbooks, and articles (more than 20) in: "Using Demonstrations for providing Pupil Experiences in Thinking," *Science Education,* 34, No. 4, October, 1946; "The Department of Science: A Handbook," *University High School Journal,* X, No. 3, 1930; *School Science and Mathematics; Education; 46th Yearbook of the National Society for the Study of Education; 3rd and 4th Mental Measurements yearbooks; 1946 yearbook of the National Science Teachers Association; Review of Educational Research; American School and University; 50th Anniversary Volume of the Central Association of Science and Mathematics Teachers;* and *Bulletin of the National Association of Secondary School Principals.* Other publications include Dr. Cahoon's doctoral study of the University of California: *Needed Laboratory Experiences for High School Science Teachers;* contributor to the volume *Demonstrations and Laboratory Experiences for the Science of Aeronautics,* McGraw-Hill Book Company, 1945; and co-author with John S. Richardson, *Methods and Materials for Teaching General and Physical Science,* McGraw-Hill Book Company, 1951.

Dr. Cahoon has been an active member of numerous committees at Ohio State University, the state of Ohio Department of Education, and in such organizations as the National Association for Research in Science Teaching, the Association for the Education of Teachers in Science, National Cooperative Committee of the American Association for the Advancement of Science, National Science Teachers Association, and the Ohio Junior Academy.

Dr. Cahoon served as President of the western section of the Association for the Education of Teachers in Science. He was Vice-President (1941), President (1942), and member of the Executive Committee (1943, 1944, and 1945) of the National Association for Research in Science Teaching.

Membership in organizations include: National Association for Research in Science Teaching, Association for the Education of Teachers in Science, American Association for the Advancement of Science, National Education Association, National Science Teachers Association, Ohio Academy of Science, and Phi Delta Kappa. He is listed in *Leaders in Education.*

Dr. Cahoon has a down-to-earth philosophy as regards the teaching of science. He believes science teaching should be vitally concerned with problems of the community, conservation, school gardens, and aviation. Workshops and education television programs evoked his interest and active participation.

Dr. and Mrs. Cahoon are now living on a small farm about twenty miles northeast of Columbus. His address is: Route #2, Galena, Ohio.

Dr. Cahoon is admired for his outstanding ability, his innate sense of modesty and humility, and his many fine contributions, over a full life-time, to the field of science education. His many friends, colleagues, and former students join with the writer in extending to Dr. Guybert Phillips Cahoon, Twelfth President of the National Association for Research in Science Teaching, their best wishes and pleasure in his being made recipient of the Twenty-Sixth Science Education Recognition Award.

CLARENCE M. PRUITT

REGIONAL MEETING OF THE ASSOCIATION FOR THE EDUCATION OF TEACHERS IN SCIENCE OCTOBER 27 AND 28, 1960

TEACHERS COLLEGE, COLUMBIA UNIVERSITY

NEW YORK 27, NEW YORK

Thursday, October 27, 1960: MORNING SESSION, Room 256, Thompson Hall

9.00 A.M. REGISTRATION AND COFFEE HOUR

10.00 A.M. WELCOME: Frederick L. Fitzpatrick, Chairman, Department of Teaching of Science, Teachers College, Columbia University

10.15 A.M. *Approaching the Draft of a Policy for Science Teacher Education,* John R. Mayor, Director of Education, American Association for the Advancement of Science

11.15 A.M. SYMPOSIUM: The Productive Science Teacher, Chairman: Victor L. Crowell, Trenton State Teachers College

1. *Characteristics of the Productive Science Teacher,* Fletcher G. Watson, Harvard University
2. *Criteria for a Program to Prepare the Productive Science Teacher,* David S. Sarner, Temple University
3. *Criteria for Discovering Potentially Productive Science Teachers,* Robert Carleton, National Science Teachers Association

* * * * *

1.30 P.M. LUNCHEON SESSION, Men's Faculty Club

Lessons from Britain, Willard J. Jacobson, Teachers College, Columbia University

3.00 P.M. AFTERNOON SESSION, Room 256, Thompson Hall

Meetings of the Working Committees
Assignments and meeting rooms to be announced

5.00 P.M. Meeting of Officers and Executive Committee, Room 412, Teachers College, Main Hall

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6.30 P.M. DINNER SESSION, Men's Faculty Club

The Proposed AETS Constitution, George Zimmer, Fredonia State College

* * * * *

Friday, October 28, 1960: MORNING SESSION, Room 256, Thompson Hall

9.00 A.M. Meetings of the Working Committees, continued

11.00 A.M. Meeting of the Working Committee, Representative and Topical Area Chairmen

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12.00 M. LUNCHEON SESSION, Men's Faculty Club

A Process-Centered Science Sequence, Glen Heathers, Director of Experimental Teaching Center, New York University

* * * * * *

2.00 P.M. AFTERNOON SESSION, Room 256, Thompson Hall

Presentations of the Summary Reports by Topical Area Chairmen
Chairman: George Pitluga, Oswego State College

ASSOCIATION FOR EDUCATION OF TEACHERS IN SCIENCE

REPORT OF BUSINESS MEETINGS OF OCTOBER 27, 1960

An official business meeting of the Association for the Education of Teachers in Science was held October 27, 1960 at the Men's Faculty Club of Columbia University. This was followed by a short business meeting of the Eastern Regional Section of the Association.

At the official business meeting of AETS a draft of the Constitution for the organization was considered along with changes suggested by the Executive Committee. A Constitution and a set of By-laws were adopted by the membership of AETS, and they are now the official Constitution and By-laws of the national organization. Copies of the Constitution and the By-laws will be sent to all members of the organization.

EASTERN REGIONAL BUSINESS MEETING

At the annual business meeting of the

Eastern Regional Section the following officers for the Eastern Region were elected:

President—Victor Crowell, Trenton State College
Vice-president—David S. Sarner, Temple University
Representative to Executive Committee—Hubert Evans, Teachers College, Columbia University
Secretary-Treasurer—Jay W. Erickson, Teachers College, Columbia

The membership of the Eastern Region voted to continue holding its fall and spring meetings in very much the same way as in the past. The cordial invitation from Harvard University to hold the spring meeting there was accepted. One of the orders of business at that meeting will be the consideration of by-laws for the Eastern Regional Section.

The following meetings of AETS are now definitely scheduled:

March 28 and 29, 1961—Chicago, Illinois. Annual meeting of AETS in conjunction with NSTA
May 5 and 6, 1961—Cambridge, Massachusetts. Spring meeting of Eastern Regional Section at Harvard University
October 26 and 27, 1961—New York, New York. Annual fall meeting of Eastern Regional Section at Teachers College, Columbia University

Submitted by:

Jay W. Erickson
Secretary-Treasurer,
Eastern Region of AETS

CONSTITUTION—THE ASSOCIATION FOR THE EDUCATION OF TEACHERS IN SCIENCE

Art. I. The Organization

Sec. A. Name
The name of this organization shall be: *The Association for the Education of Teachers in Science.*

Sec. B. Purpose
The purpose of this organization shall be to foster the improvement of the education of teachers in science.

Sec. C. Membership
1. This association shall be composed of regional sections.
2. Regional sections shall be composed of individual members who: (a) shall be active members of The National Science Teachers Association; and (b) shall be actively concerned with the education of teachers in science. An active member of the association shall be any member of a regional section, as defined above, who has paid his national and section dues.

Sec. D. Relationship to other organizations
1. This association shall be a section of *The National Science Teachers Association.*
2. This association shall be an affiliate of the *Associated Organizations for Teacher Education.*

Art. II. Officers

Sec. A. The officers of the association shall be a President, President-elect, one or more regional Vice-Presidents, and a Secretary-Treasurer.

Sec. B. Executive Committee
1. The executive committee shall be composed of the President, the immediate past President, the President-elect, the Secretary-Treasurer, one member selected by each regional section, and such other members as the executive committee shall be authorized to appoint in the By-Laws. The Executive Secretary of the National Science Teachers Association or such other person as that organization

shall appoint shall be an ex-officio, but non-voting member of the executive committee.

2. It shall be the function of the executive committee to promote the purpose of the association within the limits of this constitution.

3. A quorum for a meeting of the executive committee shall be two-thirds of the regular voting members of the committee.

Sec. C. Duties of the Officers

1. President

a. The president shall be the executive officer of the association, and as such shall carry out the policy of the association.

b. He shall preside at all meetings of the association and of the executive committee, and shall carry out any other duties assigned to him in the By-Laws.

2. The President-elect

a. The president-elect shall serve in the absence of the president at any business meeting, and shall carry out any other duties assigned to him by the executive committee or in the By-Laws.

3. Secretary-Treasurer

a. It shall be the duty of the secretary-treasurer to maintain all permanent records of the association, and any other duties assigned to him by the executive committee or in the By-Laws.

Sec. D. Election of Officers

1. The president-elect shall succeed the president. The term of the president shall be one year beginning with the close of the regular annual meeting.

2. The president-elect shall be elected by a majority vote from the nominees selected by the nominating committee. This vote is to be by ballot, to be submitted to all members not less than thirty days before the regular annual meeting, and to be returned to the secretary-treasurer for tally prior to that meeting. His term of office begins with the close of the regular annual meeting.

3. The secretary-treasurer shall be elected by a majority vote from the nominees selected by the nominating committee. This vote is to be by ballot, the same as that for president-elect. His term of office shall be for a period of three years beginning at the close of the annual meeting at which he was elected, and he shall not succeed himself.

Art. III. Regional Sections

Sec. A. Regional sections shall operate under the provisions of this Constitution and By-Laws.

Sec. B. Regional sections shall be governed by their own By-Laws provided such By-Laws are not inconsistent with this Constitution and By-Laws. Such regional By-Laws shall provide for a presiding officer who shall be a regional vice-president of the association.

Sec. C. Regional sections shall be accepted into the association by having their By-Laws approved by the executive committee of the association.

Sec. D. Each regional section, after approval by the executive committee, shall be defined in the

By-Laws. This shall include identification of the section, and the date of approval.

Art. IV. Meetings

Sec. A. The association shall hold its regular annual meeting at the same time and place as the National Science Teachers Association, and such other meetings as may be determined in the By-Laws.

Art. V. Amendments

Sec. A. Amendments to this Constitution may be submitted by a petition of twenty active members and adopted by the following procedure.

1. The proposed amendment shall be submitted to the executive committee for its consideration.
2. The executive committee shall present the proposed amendment with its recommendations to the members at a regular annual meeting. To receive further consideration the proposed amendment must be approved by a majority vote of the active members present.
3. The proposed amendment shall then be submitted to all active members of the association, by mail, not less than thirty days before the next annual meeting, at which time it shall be open for discussion and vote. A two-thirds majority of those active members voting, absentee ballots to be counted provided they reach the secretary-treasurer for tally prior to the meeting, shall be necessary for approval.

Sec. B. Changes in the By-Laws may be proposed by a petition of twenty active members of the association and acted upon by a majority vote of those active members present at a regular annual meeting.

Art. VI. Adoption

This Constitution shall be considered to be in effect when it has been submitted to all persons presently considered to be members of the Association for the Education of Teachers in Science and has been approved by a majority vote of those present at the meeting to be held in New York City, October 28, 1960. Absentee ballots to be counted provided they reach the secretary-treasurer prior to the meeting.

APPROACHING THE DRAFT OF A POLICY FOR SCIENCE TEACHER EDUCATION *

JOHN R. MAYOR

Director of Education, American Association for the Advancement of Science, Washington 5, D. C.

REPORTS FROM THREE AAAS GROUPS

A PRINCIPAL interest of the AAAS Cooperative Committee on the Teaching of Science and Mathematics for nearly 20 years has been the education of science teachers. During the five and one-half years of the Science Teaching Improvement Program, STIPS of AAAS, this same interest has been continued, although the STIP activities have been in other directions, not so directly related to teacher education, as well. During the period of a little more

* Abstract of a paper presented at the fall conference of The Association for the Education of Teachers in Science, New York City, October 27, 1960.

than the past six months, three groups in some way associated with AAAS have issued statements on the education of science teachers, particularly with reference to the content of the major in science of science teachers. It should be clear that AAAS is a scientific society and that the society, through its official representatives or the Board of Directors has, in no instance, endorsed any of the sets of recommendations. These recommendations should be considered as reports of the committee, project, or commission which sponsored them, namely the AAAS Cooperative Committee, the NASDTEC Teacher Preparation—Certification Study, and the Joint Commission of the American Association of Colleges for Teacher Education (AACTE) and AAAS on the education of teachers of science and mathematics. (NASDTEC means National Association of State Directors of Teacher Education and Certification). The first of these, the recommendations of the AAAS Cooperative Committee, are widely known and already have been influential under the heading of the Garrett Report named for Professor A. B. Garrett, Department of Chemistry of Ohio State University, who was chairman of the subcommittee which prepared the report.

A careful study of the three sets of recommendations will show some differences. There is general agreement among the three that approximately half of the time of the prospective teacher should be devoted to the study of science, that some work in professional education is essential particularly as related to science teaching; and that general education is an important part of the total program. The specific number of hours recommended in the various science subjects differ. The Joint Commission report places greater stress on the idea of the education of a teacher of the physical sciences and the education of the teacher of biological sciences, while the Garrett report makes recommendations for the education of a chemistry teacher, a physics teacher, a biology teacher, and so forth. The recommendations of the Garrett Committee, for example, were highly influential and useful in the Regional Conferences of the NASDTEC Teacher Preparation-Certification Study. The recommendations of the Joint Commission were known to the subcommittee of the Cooperative Committee of which Garrett was chairman. There has been no attempt however on the part of any of the groups to reach specific common agreements. While in each instance, those working on the recommendations would have preferred to make the recommendations without expressing them in terms of semester hours, in only the NASDTEC study has this been realized in part. The teacher certification officers in the 50 states intend to produce a set of guide lines which will not be expressed in terms of semester hours. As you will note from the documents which will be available to conference participants, this goal has not yet been completely realized. I think that it can be.

The work of the Joint Commission was broadly conceived and it was the hope of members of the Joint Commission to promote experimentation in both the science content preparation of the science teacher, and the professional aspects of the program. However, funds for promotion of the research, as conceived by the Joint Commission, did not become available and the work of the Joint Commission probably has been terminated. Since the start of the work of the Joint Commission the very wide development of summer, academic year, and inservice institutes has provided for a very considerable experimentation in science courses for teachers. Still, it seems to be pretty much a national pattern, that special courses in science are offered for inservice teachers, and the traditional courses in many of the colleges and universities are offered for the pre-service teacher. However, the inservice experimentation has already affected, in part, the offerings for the preservice teacher and should be much more influential in the future.

PROFESSIONAL EDUCATION FOR SCIENCE TEACHERS

In view of this experimentation through the institute programs, largely of the National Science Foundation, under the second grant to AAAS by the Carnegie Corporation, one of the four programs being supported is a program of Studies in Teacher Education, in which participants are experimenting with various aspects of the professional education requirements for prospective science teachers. Nine colleges and universities are cooperating this year in this work. Each has developed its own program. The colleges were chosen for participation, with some financial support from AAAS and the Carnegie Corporation, by a panel of specialists.

The University of Arizona is conducting a science seminar at which scientific papers are presented and considered, both from the scientific and pedagogical points of view. San Francisco State College has developed a science teaching center, not a new idea in itself, but one which, as applied to the professional education of the teacher, has some new aspects. Emory University and the University of Tennessee have a program in which part of the required student teaching may be met through work as laboratory assistants at the college level. Emory University and Bucknell University are experimenting on tests which might be given to prospective feachers and, which upon successful completion, would partially satisfy requirements for graduation. Emory University is experimenting with a course in mathematics for elementary school teachers and Hunter College is developing a science course for elementary teachers. Oklahoma State University has a program in which elementary teachers do most of their student teaching during the junior year and then this experience is used as a basis for motivation of the study of science during the senior year.

Two new programs for this academic year are those at the University of Hawaii and the University of Delaware. In both of these, consideration is given to the new curriculum materials in the student teaching program, at the University of Hawaii, beginning in the freshman year. The University of Delaware project is a research investigation of problem solving, involving both prospective science teachers and prospective English teachers. In Delaware and Hawaii, the work this year with support from AAAS, can be considered only pilot studies since their major research concept is much larger than one which our funds can support.

Further interest in the education of the science teacher is indicated by the program of research grants to small colleges. Sixteen such research projects, involving preservice teachers, are being supported at this time. This program was developed upon the assumption that the prospective science teacher needs to be in the environment of scientific research. In many ways, the smaller colleges do a better job of preparing the undergraduate to teach in the sciences. The greatest shortcoming of small colleges is the lack of research participation on the part of staff members of the small colleges. Indications are that this program has been a good "shot in the arm" for those few colleges which are taking advantage of it.

TEACHING SCIENCE IN THE ELEMENTARY SCHOOL

The development of programs for science teachers, 1960, must take several directions. A most difficult and important problem to consider is the pre-service education of science teachers to be developed through a four year undergraduate program. Other programs must be a continuing and constant concern of the Association for the Education of Teachers in Science. These are: the master's degree program; study beyond the master's degree; study beyond the bachelor's degree for inservice teachers; inservice courses within the school system; preparation of special teachers of science for the elementary school; and the preparation

in science of the elementary teacher. Indeed, it is these latter two on which least is now available in the literature and for which existing programs seem less satisfactory. There is a growing trend in elementary education programs to ask elementary education majors to specialize in one area, probably to the extent of a minor. This is a development which should and will be continued. The special interest area should be science for approximately one-half of the elementary teachers if mathematics is included as one of the sciences.

A second of the activities of STIP under the second Carnegie grant, is a study on the Use of Special Teachers of Science and Mathematics in Grades 5 and 6. This study is being carried on with the cooperation of four school systems, and is thought of as a two year study. Little of the objective evaluation will be available before the end of the second year, June 1961. However, there is indication of widespread interest in the use of special teachers. I am sure all of you could supply the names of school systems in various parts of the country where special science teachers are being used in the elementary school. Whether or not we agree that special teachers are the answer for the future, it seems clear that in the next decade, this procedure will be tried in more and more school systems.

CURRICULUM STUDIES

Recently I was asked by the director of teacher education and certification in the State of Kentucky to assist in planning a program for science and mathematics college staff members, to consider problems of teacher education and particularly a basis for the approved program approach in teacher education in Kentucky. It was my suggestion that the principal consultants and speakers on the program be the directors of the various curriculum studies in science and mathematics, and this suggestion was carried out. In my opinion, this was one of the most fruitful conferences of the kind that I have seen. Whether or not you think the sample courses produced by the curriculum studies are sound, these studies do serve as a means of opening minds and to cause college staff members to see the necessity for re-examination of old procedures, old courses and old courses of study. In my opinion, as of this date, the most important single event in education, and in science education in particular, of the past quarter century, has been the development of these sample courses for use in high school science classes. This point of view can be supported for many reasons.

Two years ago, I would have said the most important event was the development of the summer institutes of the National Science Foundation. While the institutes continue to offer tremendous advantages to science teachers, they have not served as well in bringing about the open mind and the experimental point of view as the curriculum studies have. In any consideration of science teacher education programs by this conference, I would strongly urge that special attention be given to the implications of the science curriculum studies at the secondary school level which soon will be extended in the sciences, both to the college and elementary school levels, and with continued generous support on the part of the federal government.

ISSUES FOR CONSIDERATION

In an introductory paper for a conference of this kind, it seems appropriate to identify certain of the issues, to which careful thought should be given. Important issues for consideration are the following:

(1) Would a job analysis for the science teacher be helpful?
(2) For what categories of science teaching shall our undergraduate programs be planned?
(3) What part of the total time available is needed for the study of science at the undergraduate level?
(4) Should the courses in science offered for the prospective teacher be special courses to which only prospective teachers are admitted, or should they be the courses leading to a single subject major, which often

are criticized as being courses in preparation for the Ph.D. degree?

(5) How can the professional education program for the prospective science teacher be improved and in particular, how much time can safely be allowed student teaching?

(6) What science and science education courses should be recommended for the elementary teacher and for science specialists at the elementary school level? What are ideal programs and what are minimal programs?

(7) What must be done to provide for the needs of inservice teachers in credit courses and, within the school system courses without credit?

LESSONS FROM BRITAIN *

WILLARD J. JACOBSON

Teachers College, Columbia University, New York, New York

To the inveterate Anglophile, there are many lures that entice him to a study of Britain and British education. Those who have admired Britain in her "finest hour," respected the remarkable self-discipline of the British people under fire, envied their balanced self-criticism of their life and institutions, and treasured the memories of searching discussions and debates over far-ranging topics, will be predisposed to look for some of the explanations of these attributes in the education of British children and youth.

To the science educator and scientist who admires the remarkable contributions of British men and women to science, there is an additional lure to study British science education. What kind of science education do we find in the nation that has produced Newton and Darwin, Davy and Faraday, Tyndall and Kelvin, Rutherford and Fleming, and a host of others? What kind of science teachers does such a nation have and how are they educated? These are exciting questions. We may never get totally adequate answers.

Some Characteristics of British Life. All educational systems are developed in the context of the society which they serve. There are many characteristics of British life that have influenced the development of science education. Three are especially noteworthy.

* Paper given at the Eastern Regional meeting of the Association for the Education of Teachers in Science at Teachers College, Columbia University, October 27, 1960.

The British people prize their liberty. It is said that all democratic nations believe in liberty, equality and fraternity. But, if the British have to choose between these, large numbers of them would choose liberty. In fact, individuals and communities in Britain will make considerable sacrifices in order to retain their freedom. This emphasis on liberty and freedom leads to great variety in schools and educational programs. Within the British Isles it is possible to find schools that range across the spectrum from severely autocratic to those that are at the extreme of the free and the progressive. Variety is one of the most important characteristics of British schools.

There is a great stress on empiricism in British society. New science courses and approaches to teaching are tried and tested. If they work, they are continued. If they are unsuccessful, new attempts are made. At times, there is an impatience with theorizing. There has been relatively little attention to theory in education including science education. Surprisingly, although there is a growing interest in research into science education, the attention and resources directed to science education research have been limited. Experiences are interpreted largely by a "common sense" approach by the people most directly involved. However, educational practice appears to be based largely upon these interpretations of experience.

Tradition is an important dimension of British life. A major policy statement on

science in secondary schools [1] has a chapter entitled "The English Tradition of Science Teaching." This follows a chapter with the title "A Hundred Years of Science Teaching." Two very important traditions that are highlighted are the emphasis upon practical (laboratory) work and the relatively high degree of specialization that occurs in the secondary schools and in the universities. It would be unlikely that any observer from another land would fail to note the importance of these two traditions in science teaching throughout Britain.

THE EDUCATION OF THE BRITISH SCIENCE TEACHER

The British educational system is a large, complex undertaking, characterized by variety, empiricism and tradition, and worthy of a much more extended analysis than can be encompassed in a short paper. Instead of an extended analysis, I should like to trace briefly the education in science that the science teachers of tomorrow are now receiving in British primary and secondary schools and in the universities, placing special emphasis on the lessons for us as we plan for the education of our teachers of science.

The Primary School. The similarities between the British primary schools and their American counterparts are much greater than their differences. In fact, competent students of comparative education are beginning to suggest that a general pattern of primary education is emerging in the free world. Certainly, there are great similarities between the British primary schools and American.

In some British primary schools, children have excellent opportunities for experiences in science. There is considerable emphasis on project work by individuals and small groups. Children use materials from the home and community to make equipment and apparatus. For example, a small group of boys made their own telescope and used it to make a very fine map of the moon. From this they were moving on to try to find a relationship between the phases of the moon and the height of the tides in the local harbor. I was impressed by the children's reports of their studies and with the ability of the teachers to work with large groups of children having a wide range of abilities as they worked as individuals or in small groups. In other British primary schools there are no science programs. However, all science educators and almost all general elementary educators that were queried stated that primary school science was an important area that should be developed in the immediate future.

Lesson 1—*Primary school children can carry out and demonstrate experiments and other science activities that are interesting and educational to all.* In some British schools, primary school children report their science investigations as individuals or as small groups. These reports usually include demonstrations as well as reports of results. The teachers work with the children in the preparation of their reports and usually lead the discussion that follows. They insist that the children test their apparatus and practice their presentations before giving it to the class. It would seem that, if in the future some of these youngsters were to decide to become science teachers, these experiences should stand them in good stead.

Lesson 2—*Stimulating science experiences can be developed as children study their local communities.* Often, in British primary schools, children engage in a rather intensive study of their local community. This study leads them into all of the areas of the primary school curriculum. Through these studies youngsters get a better understanding of their communities, the subject matter areas, and how the understandings in these subject matter areas apply in their local communities and regions. In one school a group of ten and eleven year olds, as they studied their local community and

[1] *Science in Secondary Schools.* Ministry of Education Pamphlet No. 38. London, England: Her Majesty's Stationery Office, 1960.

region, learned about the topography of the local region and the forces that had shaped it, the geology of that part of England, how their electric energy was generated and transmitted, some of the characteristics of the local flora, the wild animals to be found in the region, the major industries and the processes and raw materials that were used, some of the factors that at one time had made their harbor an important port, some of the factors that influence the local weather conditions, and the physical principles that were involved in the camera obscura that was one of the attractions in the city. The teachers appeared to be very successful in helping children become better informed about their community and region and at the same time gain a better understanding of basic scientific principles.

Lesson 3—*Major field trips extending over a period of several days are a stimulating and profitable experience for children in schools in large cities.* In some of the schools in London, children in the final year of the primary school take week-long field trips to other parts of the country. In some cases, seaside vacation resorts are used out of season. Through imaginative planning, these field trips provide an approach to a variety of experiences ranging from the study of tides and shoreline erosion to the ecology of life at the edge of the sea. Certainly, these field trips provide opportunities for significant, memorable experiences in science for children from the heart of large urban centers.

At the Age of Eleven. One of the most controversial aspects of the British education is what is known as the "eleven plus examination." At about the age of eleven most British youngsters take an external examination that has come to be called the "eleven plus examination." The score a youngster receives on this examination, to a large extent, determines his future educational opportunities. Roughly, the top 20–25 per cent can go on to the grammar schools which are the road to future university education. The remainder will go on to secondary modern schools until at least the age of 15 and after that have access to a variety of technical, vocational and commercial schools.[2] Obviously, the future teachers of science are drawn largely from the 20–25 per cent who scored well on the "eleven plus" examination.

General Studies in Science for Young People between the Ages of 11 and 15. The question of what kind of science programs should be developed for young people in the early years of the grammar school is a highly controversial one. Some hold that the study of specialized sciences such as biology, chemistry and physics should begin in the first forms of the grammar school. At the other pole in the controversy are those who support a broad program of science, such as general science, for the early adolescent. The controversy is complicated by the feeling among many science teachers that the proposal to have general science is used by some school administrators to reduce the total amount of school time devoted to science. The comparatively high degree of specialization in the training of grammar school science teachers and the fact that many general science courses actually are divided into sections devoted to biology, chemistry and physics are other factors that complicate the issue. Undoubtedly, this vigorous controversy will continue. The cogent statement of a group of H. M. Inspectors of Schools contains a lesson for our efforts here in the United States.

Lesson 4—*A program of general studies in science is suggested for young people between the ages of 11 and 15.* In describing this course the inspectors say,[3]

> First it will be a broad course embracing the study of elementary phenomena in biology, chem-

[2] There is a growing number of comprehensive schools to which youngsters can go regardless of their scores on the "eleven plus" examination. Within the comprehensive school students are usually grouped into "streams" on the basis of their ability as evidenced by examination results, grades, and teacher ratings.

[3] *Op. cit.*, p. 46.

istry, physics, geology and astronomy. Secondly, the topics studied should be selected for their intrinsic interest and importance. It would be a gross mistake, for example, to divide the available time equally between these branches in the hope of being fair to all. The attempt by many schools to cut the Gordian knot by giving equal time to the first three has equally little to commend it. Thirdly, throughout the treatment must run a spirit of investigation. Fourthly, observation and experiment at first hand are of crucial importance. Fifthly, treatment and to a less extent choice of topics should be modified to match the ability of the pupils who must be persuaded to think to the limits of their intellectual powers. Lastly, some differentiation may be expected according to sex, the school's environment and the future careers to the pupils, but the scope for this is limited by the necessity to acquire fundamentals.

Science for Young People Over 15. It is in the education of the older adolescent that British and American schools differ the most, and it is probably in this area that we have the most to learn from our British friends. By the age of 15, most students in British grammar schools have to decide whether they are to specialize in the arts or the sciences. In fact, in many schools able boys practically speaking have to make this decision when they are 14. Having decided, the boy or girl who will become the science teacher of the future will devote as much as 75 per cent of his school time to the study of science.[4] This may be compared to the 20 to 30 per cent of the available study time that the American high school student will devote to his major field of interest. Many competent observers both British and American have estimated that the British student upon leaving the sixth form at the age of 18 will be about two years in advance of the American high school graduate in terms of level of scientific knowledge.[5]

Education in the upper forms of the grammar school is often of very high quality. Undoubtedly, some of the outstanding teachers in Britain work with the young people in the sixth forms. The groups are often comparatively small. I saw groups of five or six students working under the direction of highly competent teachers, and much of the work that these able young people do is laboratory work of various kinds.

Students in the upper forms of the grammar school sometimes have opportunities to take part in research projects under the guidance of their instructors. In one school, students participated in investigations in plant and animal ecology. The students published their papers in the journal of the local society, and they had a chance to work with the instructor as he developed two outstanding books on ecology. In another school, students worked with the chemistry instructors as they investigated various ways of treating aluminum electrolytically and how various samples of treated aluminum withstood corrosion in both rural and urban areas. In both these examples, young science students had a chance to see how a research project is set up, some of the procedures that are followed, and actually took part in some of the activities.

Lesson 5—*It is very important that young people have experiences in depth in science in which there are opportunities to investigate questions and problems in science and where creativity is encouraged.* This probably is the most important lesson from Britain. The young people who are genuinely interested in science and ready to commit time and energy to scientific pursuits should be given opportunities for experiences in depth in science with the assistance and guidance of highly competent and sincerely dedicated science teachers. Our

[4] By assuming that the student will devote almost all of his homework time to the study of his specialized subject because this is what counts for university entrance, Peterson in his controversial study concluded that many British students will devote about nine-tenths of their study time to their area of specialization. Peterson, A.D.C. *Arts and Science Sides of the Sixth Form.* Oxford, England: Oxford University Department of Education, 1960, p. 7.

[5] A summary of the observations of British and American exchange teachers that substantiates this observation may be found in "Exchange Teacher: Comments on Some Schools in Great Britain and America" London, England: Conservative Political Centre, 1960.

young people deserve this opportunity and our national welfare demands it.

Although there may be general agreement as to the desirability of experiences in depth in science, the ways in which these experiences can be achieved are not as clear. Many observers, both British and foreign, believe that there are serious weaknesses in the extreme specialization to be found in many British grammar schools.[6] There is a widespread concern that future scientists be educated as well as trained, and there has been much discussion of the dangers of having groups of people who are so narrowly educated that they cannot converse with each other. There is also, of course, the danger that, when the choice of specialization is made at the age of 14 or 15, it is on the basis of fleeting interest rather than deep commitment.

It may be that experiences in depth can be provided through new approaches that are not yet in widespread use in either country. Perhaps, this need can be partially met by the summer science seminars that have been set up by a few communities. In these seminars, students devote all of their study time to investigations in science. The experiences that young people have in junior science academies and local science societies may also partially meet this need. This approach has the advantage of utilizing more fully the intellectual resources of our communities. Certainly, there is a need for further experimentation with ways to give young people experiences in depth in science.

Teacher Education in Science. The most common path for science teachers in England leads through three years of university education plus one year of professional training at an institute of education. In most universities almost all of the formal education is in the student's area of specialization. In the institute of education, the prospective teacher will take part in such courses as principles of education, comparative education, educational psychology, English education system, history of education, special methods courses, tutorials and teaching practice.

Lesson 6—*The future teacher of science should have experience in setting up and carrying out demonstrations, planning laboratory work, preparing teaching materials and building equipment.* Methods of teaching, particularly with invented equipment, receive a great deal of attention in British science teaching circles. A great deal of imagination and effort goes into the development of new and better ways of teaching various areas of science. In fact, a large fraction of the *School Science Review*[7] is devoted to the exchange of ideas with regard to methods of teaching. In the institutes of education, future science teachers begin learning how to make and use materials and equipment for science teaching.

Lesson 7—*Well planned and carefully supervised teaching practice is of special importance in the education of a science teacher.* Several times during the year of professional education, the future teachers visit a school as a group with the guidance of a tutor, observe the teaching of an experienced science teacher, and discuss with him his approach to teaching and various problems that he encounters in his work. These observations and discussions are an effective means of helping students to see and evaluate a variety of approaches to teaching.

The future teachers engage in teaching practice in nearby schools for three blocks of time during the course of the year of professional education. They are super-

[6] Perhaps, the most cogent discussion of some of the problems that arise from specialization is to be found in C. P. Snow's, *The Two Cultures.* Although there is a problem of the "two cultures" in all western countries, some observers believe that it is more acute in nations where specialization in education occurs early. Snow, C. P., *The Two Cultures and the Scientific Revolution.* Cambridge, England: Cambridge University Press, 1959.

[7] *The School Science Review.* London, England: John Murray Publishers. *The School Science Review* is the official publication of the Science Masters' Association and the Association of Women Science Teachers.

vised by tutors from the institute and by cooperating teachers in the secondary schools. During the final block of teaching practice an external examiner may also observe students teach. Both students and tutors attest to the value of this teaching practice.

Lesson 8—*Future science teachers should consider and study the social significance of science, the history of science, the relationships between science and other areas of study, and the problems of planning science programs.* The following are examples of topics that are sometimes considered and discussed by future science teachers:

Many British young people are deeply concerned about the possibility of nuclear warfare. One of the most widely debated issues is whether Britain should unilaterally dispose of its nuclear weapons. Future teachers discuss this issue in order to become better prepared to discuss it with their students.

One of the traditions in British science teaching is that students should have an opportunity to be placed in the "attitude of the discoverer." Students work through some of the classic experiments in science that led to important discoveries. The British science teacher is helped in doing this by having ready access to some of the finest science museums in the world. Although some limitations of this heuristic method are recognized, it does help students to get a clearer picture of what is involved in scientific investigation and a better understanding of the history of science.

At times tutorial groups in science will meet with groups from other departments. They will meet, for example, with the group in mathematics education to discuss the relationships between the science program and the program in mathematics.

Some British science educators believe that future teachers should have some experiences in planning new science courses. One of the needs that is being felt in British education is for an effective science course for the future lawyer, business man and civil servant who is in the arts side of the sixth form. One group of future science teachers prepared such a science course, compared it to some that are now in existence, and wondered whether there were at that very moment future teachers of the arts who were planning similar programs for those in science.

Our educational programs here in the United States are periodically reexamined and reappraised. If we apply a pinch of humility and a dab of ingenuity, we may be able to profit from the experiences of others as well as our own. What kinds of science courses have been developed in other lands? What can we learn from them? What approaches to teaching are used elsewhere? What from the experiences of others can We adapt to build a better education at home? A willingness to look, to listen and to learn can be an important source of strength for us as we strive to create more imaginative and challenging science programs.

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A PROCESS-CENTERED ELEMENTARY SCIENCE SEQUENCE *

GLEN HEATHERS

Director, Experimental Teaching Center, School of Education, New York University, New York, New York

THE question for our consideration is this: Should the elementary science sequence be arranged, not in terms of science content, but in terms of levels or stages of sophistication in the scientific process of inquiry? Obviously, the question is not whether the study of scientific method should be included in elementary science along with science facts, concepts, principles, and applications. Everyone agrees that the study of the scientific methods of investigation belongs in elementary science. The question, rather, is whether the focus and the organization of the elementary science sequence should be in terms of the scientific process of inquiry rather than in terms of science content.

Before getting to the question, let me tell of the circumstances that place me on this spot before you, and let me mark out the rather narrow boundaries of my competencies to discuss the science curriculum. In the School of Education at New York University, our Experimental Teaching Center is helping the school systems at Long Beach and Ossining in New York, and the Pennsbury Schools at Fallsington, Pennsylvania test a semi-departmentalized plan for organizing instruction in the intermediate grades of the elementary school. This is Dr. George D. Stoddard's "dual progress plan" that provides non-grade-level grouping and advancement in science (as well as in other subjects). In the plan, every child in grades 3–6, or 4–6, is taught science one full period each day, a total of about 200 minutes per week. He is taught by an elementary teacher who specializes in teaching science full-time. He is taught science in a room equipped as a science laboratory.

The dual progress plan requires some changes in the science course of study, and invites other changes. Since students are grouped for science instruction without regard to grade level, and since the distance they progress along the science sequence in a year depends on their learning rate, a non-grade-level sequence must be provided to guide the teacher. Also, since the dual progress plan was designed to strengthen the intellectual quality of elementary education through placing greater stress on problem-solving thinking, self-directed learning, and creativity, the selection of topics for the science sequence to be used in the plan should be made in ways that will foster these basic learning goals. For these reasons, the Experimental Teaching Center finds itself engaged in the task of revising the elementary science course of study.

My qualifications for the task at hand are limited. My training and experience have been in experimental psychology, social psychology, child development, and educational psychology. I have not taught in the elementary school, and I lack specific knowledge of the contents, materials, and methods of elementary science. Given these limitations, my remarks will be mainly general and speculative, and at all points subject to correction by experts such as yourselves. I have borrowed some of the ideas in this paper from my colleague at the Experimental Teaching Center, Esin Kaya. Dr. Kaya has proposed a general curricular theory in which the sequence in any curricular area is based on a developmental sequence of psychological processes. I have been collaborating with Dr. Richard Anderson, who was on the staff of the Center, in the attempt to conceive a process-centered elementary science sequence. Also, I have benefited from the work of several

* Paper presented at meeting of Association for the Education of Teachers in Science, Columbia University Faculty Club, October 28, 1960.

others who are developing elementary science materials that stress the scientific process of inquiry. These include Fletcher Watson at Harvard; Robert Karplus at the University of California; J. Richard Suchman at the University of Illinois; Herbert Schwartz at New York University; and Jack Robbins at the Long Beach, Long Island, Public Schools.

The proper organization of the elementary science course of study depends on the answers to two questions. First, what should elementary school children learn in science? Second, how can the elementary science sequence best be organized to teach the science that elementary school children should learn?

I believe there is general agreement among science educators that children in elementary school should learn four sorts of things in science:

1. They should learn certain basic facts, concepts, and principles of physical and biological science. I would include social science.
2. They should learn certain technological applications of science in such areas as health education, machines, electrical devices, transportation, weather, the care and feeding of plants and animals, and social relations.
3. They should learn the methods of inquiry that are employed by scientists and technologists in acquiring and applying knowledge.
4. They should acquire interest in science, and attitudes and values appropriate to science. These include a pervasive curiosity; a reliance on evidence; appreciation of universal order, variety, and change; a healthy skepticism; and a relativistic view of knowledge.

It is clear that the child in elementary school cannot learn all there is to know about each of these aspects of science. What guidelines may be used in selecting topics for inclusion in the elementary science course of study, and for placing the proper emphases on the topics selected? I propose that the key is *process,* using the word in a general sense. I suggest three types of process in elementary science. One is the *process of inquiry* that is usually called the scientific method. It involves hypothesizing about antecedent-consequent relations, testing hypotheses, and stating the resulting principles or generalizations. A second refers to the *processes in nature,* the antecedent-consequent relations, that are discovered through the use of the scientific method. These processes, often called "cause-effect relations," are the heart of science. The third refers to the *process of applying knowledge* in the various technologies. Man is powerful when he employs his knowledge of antecedent-consequent relations to control nature. He manipulates "causes" to produce the "effects" he desires.

Viewed in terms of process, the four aspects of the elementary science program fit neatly together. Problems related to the interpretation and control of nature can be solved because nature is orderly and lawful. Through the scientific process of inquiry, the orderly processes of nature can be discovered and measured. Once natural processes have been discovered and measured, knowledge of them may be put to use in solving practical problems. Experience in solving scientific and technological problems builds interest in, and appreciation of, scientific knowledge and the scientific method. And such experience builds initiative and self-direction in obtaining, evaluating, and using knowledge.

The focus on process happily discourages three faults that are common in the teaching of science. One fault is teaching scientific facts that are not put to use in solving scientific problems. Instead of having children memorize the distance to the moon, the goal should be to teach them how the distance to the moon can be measured, and how to use the method of triangulation themselves in measuring distances. Another fault is teaching technological facts rather than teaching how scientific principles are put to work to serve practical ends. Instead of teaching that pulleys can be used to lift things, students should be taught how pulleys apply principles of physics. A third fault is answering children's questions instead of teaching them to answer questions through employing the scientific method of inquiry. In good part, of course,

these faults are the result of improper teaching methods. But their removal may be speeded by organizing the course of study in a way that leaves little room for them.

It may be that I disagree with some science educators in favoring the inclusion of technological applications of science knowledge in the elementary science curriculum. I do so for two reasons. One is that I believe that elementary science should teach how solutions of scientific and technological problems are related. This gives the child an appreciation both of the values of science and of the workings of science. Another reason is that much of the interest that children have in science is related to practical outcomes. Children want to know how to wire an electric circuit as well as how electricity behaves. They want to know how to make plants grow as well as what makes them grow. A fine example of effectively blending science and technology is the Macmillan Science-Life Series written by Darrell Barnard and his co-authors. This textbook series is organized about twelve "areas of human adjustment."

How much science should be taught in elementary school? The obvious answer is that each child should be taught as much science as he can learn in the time provided for science. In the dual progress plan, all children in the intermediate grades devote as much time to science as to mathematics. This is about 40 minutes per day. Non-grade-level grouping and advancement in the plan are intended to permit each child to advance as far as he can in science before entering junior high school. In the plan, some rapid learners should advance to what are now called high school levels of work before graduating from elementary school, while some slow learners will be able to advance only a half or a third as far. The important considerations are these: every child should be taught the fundamental processes of science along with basic information drawn from different fields of science, and every child should achieve mastery of each topic he studies before proceeding to the next. Mastery does not mean memorizing facts, concepts, and principles of science. Memorized information most often is of little use; also, it is soon forgotten. Mastery calls for learning science through problem-solving thinking and experimenting that is directed toward discovering and applying scientific knowledge. It also calls for an emphasis on self-direction in asking, and finding answers to, scientific and practical questions.

Thus far we have considered the first of two bases for setting up the elementary science course of study—what children should learn in science in the elementary school. The question now before us is that of sequence. How should the sequence in elementary science be established?

The courses of study in elementary science that are in use today are organized in terms of science content. There may be exceptions to this rule, but they have not come to my attention. At each grade level, the same broad areas of science are treated. Each year, the student encounters such large topical areas as the universe, the earth, living things, matter, and energy. Within each such area, the grade placement of learning materials is most often based on complexity or abstractness. Also, the material at higher grade levels builds on the foundation of knowledge about the area that was acquired at lower grade levels.

I know of one course of study in elementary science that is organized both on the basis of content and on the basis of level of sophistication in the use of the scientific method. This is the curriculum developed by Darrell Barnard and his co-authors. At every grade level, each of twelve content areas is studied. At different grade levels, emphasis is placed on different operations in the scientific method of problem solving. Thus, at grade 2, the emphasis is on learning about things through the senses. At grade 3, the emphasis is on getting answers to questions through observation and doing simple activities. In grade 4, measurement is the focus of attention. In grade 5, scien-

tific comparisons and controlled experiments are introduced. In grade 6, the student learns more about how the scientist sets up and tests hypotheses in experiments.

Now let us consider the possibility of going a step further than Professor Barnard has gone, and basing the elementary science sequences primarily on stages of sophistication in the scientific process of inquiry. Can we build an elementary science sequence where the center of attention is kept on *how* scientific questions are asked and answered, and on *how* scientific knowledge is put to use, not on *what* answers scientists and technologists have discovered? Let me offer some suggestions on what such a sequence might be like.

Suppose we were to teach young children the scientific way of thinking in somewhat the same way that a good teacher teaches them mathematics. Teaching science then would stress learning the terms, rules, and operations of the scientific method. This is the *language of science*. It applies equally well to any science content, just as mathematics applies equally well to any content.

The first phase in a science course of study that placed stress on learning the scientific method might call for teaching these things to children when they begin elementary school:

1. To classify objects in various ways in terms of such characteristics as size, shape, color, weight, and texture.
2. To arrange objects in ordered series according to their positions along each of a number of dimensions—size, color, weight, roughness, etc.
3. To observe and describe similarities and differences in objects according to presence or absence of certain characteristics, or the degree to which they represented certain characteristics.
4. To notice and describe changes in various objects in such characteristics as shape, size, color, and position.
5. To notice and describe changes in the relationships of objects—distance, direction, interconnectedness, etc.
6. To notice and describe motions of objects in terms of direction, distance, speed, trajectory, etc.
7. To produce and describe simple "cause-effect" changes through manipulating objects, and to state some simple rules that describe what happened.
8. To guess what would happen if something were done, to give reasons for expecting particular outcomes, to observe and report what actually happened, and to offer plausible explanations of wrong guesses.
9. To offer various plausible explanations for things that had happened, and to learn some of the hazards of *ex post facto* explanation.
10. To specify different ways in which certain desired outcomes might be achieved by employing simple operations with objects.

This list of suggested objectives for the first phase of the study of science obviously must be related to science content. How? For one thing, each objective should be related to content out of the child's world of experience. For another, the effort should be made to have the child relate the objective to as great a variety of content as is practicable in order to give him a generalized understanding of the meaning and usefulness of the operation. The point to hold in mind is that the primary purpose of instruction would be to teach the aspect of scientific method, not to teach any particular content. Emphasis should be kept on the process of solving problems, not on the solutions achieved.

The second phase in a process-centered science sequence probably should teach the terms and procedures required in planning and conducting simple experiments. The children would learn about independent variables and dependent variables as dimensions. They would learn to predict changes in dependent variables as functions of changes in independent variables. They would learn to test their predictions through making systematic, measured changes in independent variables and through measuring associated changes in dependent variables.

An appropriate experiment might be that of determining the relation between angle of tilt of a board and the time required for a steel ball to roll its length. Another dependent variable in the situation might be the force the ball exerted at the end of its fall. Measurements would include angle, time, and force exerted. Error in measurements would be considered. The children might learn to graph the relationships found between independent and dependent vari-

ables. They should learn to state the relationship found. Other experiments might involve studying the effects of placing weights at different distances from the fulcrum of a balance, or studying the relationship of length of time heat was applied to a vessel filled with water to the temperature of the water.

After the children had studied the basic experimental model in a variety of laboratory situations, they should be taught to analyze various non-laboratory events in terms of the model: the harder it rains, the more quickly you get wet; the faster you run, the more quickly you get tired; the farther away an object is located, the harder it is to recognize it; and so on.

Would this sort of science teaching bore children? I see no reasons why it should, provided it were well done. Rather, I expect it would fascinate children. They would be engaged the whole time in solving problems. They would be learning new and powerful ways of exploring the world, and bringing it under control. Slow learners should respond as well to such a program as gifted students; the differences between them would be mainly in the rate at which they advanced, and the richness of their knowledge.

I shall not attempt, at this time, to outline what the remaining stages in the proposed elementary science sequence might be. The task of developing such a sequence is a difficult and laborious process, and calls for the help of experts in child development, learning theory, science, and the practice of education. Developmental psychology, educational psychology, and educational practice provide many leads toward setting up a sequence in terms of the problem-solving process. But much more, and more specific, research on children's development is needed to provide sound guidelines for curriculum development. Notice how vague, and how overlapping, are these statements of how the child's potential for learning science develops with age:

Age 5 – 6	Full use of senses in investigating things.
Age 6 – 7	Beginning to generalize about the environment.
Age 9 –10	Beginning to recognize and seek out the big idea.
Age 10–11	Beginning to be able to carry out long-range study.

Obviously, our knowledge of the development of children's thinking must become much richer than this before we can use it as a dependable guide for curricular sequence. Also, we should recognize that these crude age norms were derived from the study of children who experienced today's science teaching with all its limitations. We can only guess what changes in such developmental norms would occur with first-rate science teaching from Kindergarten onward. Child development research, curricular research, and research on the teaching process, must be relied on for help in finding the answers we are seeking.

It is clear that the purposes of a good course of study in elementary science cannot be achieved without good science teaching. Today's elementary teachers know all too little about science, or about how to teach science. I suspect that a process-centered elementary science sequence would clarify, perhaps simplify, the problem of achieving good science teaching in elementary schools. With such a sequence, the heart of teacher preparation in elementary science would be a thorough grounding in the scientific process of inquiry. While a rich background of course work in the various sciences—particularly, physics, chemistry, and biology—would be highly desirable, much good science teaching could occur without it. A teacher with a working familiarity with so-called general science, and with a sound knowledge of scientific method, could probably do a workmanlike job of teaching a process-centered sequence.

It does seem unlikely that more than a small minority of general elementary teachers will possess the interests and competencies required to teach science well. For this reason, all science in the intermediate

grades under the dual progress plan is taught by full-time specialist teachers of science. To provide in future a supply of elementary teachers specifically prepared to teach elementary science, the School of Education at New York University is conducting an experimental fifth-year program to prepare elementary teachers with a specialty in science. Trainees in the program will have an undergraduate major in a science, and a sizeable part of their year of teacher education will be devoted to methods of teaching elementary science, and to practice teaching in science.

To sum up, the elementary science program I propose would incorporate these five general features:

1. All science, at least in the intermediate grades, would be taught by elementary teachers who specialized in teaching science full-time.
2. All science, at least in the intermediate grades, would be taught in classrooms equipped as laboratories for the subject.
3. Elementary science teachers would be required to have a college major in a science, and a fifth year of college devoted to teacher preparation.
4. Non-grade-level grouping and advancement would be employed as a way of maximizing opportunities for individualized teaching.
5. A non-grade-level course of study in elementary science would be provided, with its sequence organized in terms of stages of sophistication in the scientific process of inquiry.

The governing purpose of all five features of the elementary science program would be to teach all elementary children problem-solving thinking, employed with self direction and creativity, in the fascinating and powerful world of science.

A PROGRAM TO PREPARE THE PRODUCTIVE SCIENCE TEACHER *

DAVID S. SARNER
College of Education, Temple University, Philadelphia 22, Pennsylvania

MY task today is to develop a program about "what it does or should take to mold the raw material the science teacher into the accomplished performer we expect him to be." At first sight this appears to indicate a program for the *undergraduate* who has chosen the teaching of science in the public schools as his profession. On the basis of the literature and my own experience, we now know that we have as well, an even greater task before us in science education: the re-education—the retraining of the science teacher who is currently in service in our schools.

In 1957, Fletcher Watson [1] pointed out the need for course requirements for future science teachers when he suggested "full year courses in biology, chemistry, physics and mathematics totalling approximately 32 semester hours." In this same article Watson pointed out that the Steelman Report of 1946 made much the same recommendations.

In 1958, Jack Frymier and I [2] did a study in which we found that state certification requirements for the teaching of science and mathematics were too low. We suggested that if the various states did not remedy the inadequacies that exist in the certification laws, then the remedy should be applied by teacher education institutions. Rather than develop a hypothetical program, I decided to tell you of our program in Secondary Education at Temple University and let you take it from there.

In September of 1959, the Division of Secondary Education at Temple University took two important steps in the training programs of the science teacher. Both of these steps were directed toward strengthening the academic science and mathemat-

* Paper presented at meeting of the Association for the Education of Teachers in Science, Teachers College, Columbia University, October 27, 1960.

ics backgrounds of our teachers. Before last year, our program read like this:

45 semester hours of general education
29 semester hours of professional education
32 semester hours in a major field
18 semester hours in a minor field
4 semester hours in physical education
128 semester hours for graduation

Now, it is fairly obvious that this program is too heavily concentrated in the area of professional education and without specific direction in the area of the major or minor. Because of this lack of direction, over 80 per cent of our science majors elected to major in biology and botany because there were no mathematics required in these courses.

Partially as a result of our study, and, partially as a result of our involvement in the National Science Foundation Summer Institute programs, we soon realized that some drastic changes needed to be made in our science training program.

Although we were unable to eliminate some of the professional education courses, it was possible to strengthen the requirements in science. The major-minor idea was eliminated and, following Watson's suggestion, we now call for a major requirement of 54 semester hours, broken down as follows:

9 semester hours general chemistry
9 semester hours general physics
8 semester hours biology
½ yr. of zoology
½ yr. of botany
6 semester hours mathematics
All taught by the faculty of the College of Liberal Arts.

Basic requirements 32 semester hours, plus the remainder of 22 semester hours as a minor in either biology, chemistry, physics, or any other subject in the area of science.

It was our intent here to create a broad base of the physical sciences and biology, all reinforced by an introduction to mathematics, then creating enough course work in one specific area to serve us a good firm base for later graduate work.

Because we were unable to cut out some professional education courses, and I am not sure we should rule out their value, and because we were anticipating the states' move to a 60 semester hours requirement in general education, we now need 4½ years to complete our science education program.

I am not satisfied with this program, as good as we think it is, so I would suggest the following program:

I would retain the general education program of 60 semester hours as this insures a good liberal arts program in English, the social sciences the humanities and the arts, which I believe are essential to the background of all teachers;

To this, I would add 18 semester hours of professional education, of which 6 semester hours would be student teaching in the student's major field, under the guidance of an outstanding science teacher and the supervision of a science educator;

To the student teaching experience, I would add the experience to be gained while working as a member of a research team either at the University or in industry (my recent experience with my Summer Institute for High School Teachers in Research Participation has convinced me that the science teacher has much to gain from this);

Now, to this I would add the previously described base of 32 semester hours of science and math, plus the 22 semester hours in a particular area for a total of 132 semester hours or a 4 year program.

For more years than I wish to recall, I have seen science teachers come back to Temple University for graduate work in professional education. As a director of N.S.F. Institute programs at Temple, I am familiar with hundreds of science teachers who are rich in education courses and paupers in science backgrounds. This past summer, I pulled every 10th application to my institutes and I found that these science teachers who were teaching general science had an average of 6.2 semester hours in chemistry and 4.7 semester hours in physics. Obviously, something must be done. The N.S.F. programs are doing a tremendous job in their way, but the teacher training institutions must do even more.

For the second year, we at Temple have been offering the degree Master of Science in Secondary Education in the Improvement of the Teaching of Science (or math, or English, etc.).

We now offer a more realistic program to the in-service science teacher. He no longer needs to sit through 30 semester hours of graduate professional education courses—for we have cut this requirement to 14 semester hours and substituted 16 semester hours of science for them. This is how it works: A science teacher who has been accepted by the graduate college comes to me for advisement. I look over his transcript and note that he has a major in biology and little or even no courses in the physical sciences or mathematics. He is therefore informed that, before he may continue any additional graduate work in biology, he must take a year of chemistry or physics preceded by a year of mathematics (no graduate credit). Graduate credit is given for one N.S.F. Institute for a total of 6 semester hours and the remainder of 10 credit hours in science must be completed on a graduate level.

Does this work? We know it does for, already we have 45 active candidates for this degree. Here, then, are 45 teachers who will gain more science background to the benefit of themselves and their high school students.

Let us assume for the moment that we have adopted an undergraduate and graduate science teacher training program that:

1. Prepares the teacher with a sound academic basis for teaching the sciences.
2. Enables the teacher to teach science concepts and principles.
3. Allows the science teacher to place emphasis on having the students do, and not memorize facts.
4. Provides for the academically talented and the average and below-average students—all of whom will become future citizens capable (we hope) of evaluating issues advanced by scientific progress and technology.

We next need to assume that we have prepared our teachers well enough to allow them to have their graduates accepted for college. Now we find ourselves faced with another problem that we in A.E.T.S. need to consider. How can we make sure that college teaching in the sciences will continue to develop the critical-thinking, problem-solving approach with which we try to endow our students and which, we hope, they have passed on to their high school students? Unless the college science departments are willing and able to continue the presentation and philosophy presented by the P.S.S.C., the C.B.A.C., the A.I.B.S., and the 3 math programs, our work will be of little or no avail, as the colleges continue to insist on the accumulation of memorized facts to succeed in a course. We must bring the science disciplines together to come to an agreement as the college physics people have attempted to do this past summer. It is our duty as science educators to make sure that our training based upon understanding of concepts and principles of science extends from the teachers in the elementary school through the secondary school and into the colleges. Then, and only then, can we consider our problem on the way to solution.

(NOTE: Dr. Stanley Marshall and the Garrett Report of A.A.A.S. have proposed excellent programs for the training of the science teacher. This paper describes a program already in successful operation.)

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EVALUATION AND FOLLOW-UP STUDY OF A SUMMER SCIENCE AND MATHEMATICS PROGRAM FOR TALENTED SECONDARY SCHOOL STUDENTS *

William W. Cooley

and

Robert D. Bassett

Graduate School of Education, Harvard University, Cambridge 38, Massachusetts

Summer science and mathematics institutes for talented high school students have increased rapidly in number during recent years. In an attempt to inquire into the consequences of such programs, an independent study was undertaken at the Harvard Graduate School of Education to evaluate and follow-up one of these summer institutes. The particular program selected for study was conducted at Thayer Academy in Braintree, Massachusetts during the summer of 1959. Here fifty-five high school juniors, primarily from eastern Massachusetts, spent two weeks studying advanced topics in science and mathematics at the Academy and eight weeks working alongside research scientists in neighboring university and industrial laboratories.

We do not pretend that this particular program is representative of all such programs. However, we do feel that many of our results will be of interest to educators who are concerned about this type of procedure for enriching the educational experience of talented high school students. If nothing else, we hope that this effort may encourage further evaluations of this new and important educational innovation.

The general intent of these summer programs can best be described by quoting two statements of the National Science Foundation who supported programs at 137 institutions last summer. "The training offered by this program is designed to provide the superior high school student with educational experiences in science and mathematics beyond that normally available in high school courses." [1] The primary aim of the program is to "encourage the scientific interests of high ability secondary school students by providing them with opportunities to participate in study and research programs set up especially for them." [2]

Our evaluation and follow-up study had the following major objectives: (1) to determine to what extent the Thayer Academy Program accomplished its stated purposes; (2) to examine the "back to school" consequences of that program; (3) to develop procedures and identify evaluative instruments which could be used in comparing the relative merits of similar programs in subsequent summers; (4) to compare the fifty-five participants with 200 students of the same age and geographic region who are subjects in a five-year study of the career development of scientists. (The Scientific Careers Study)[3]

There were two phases to our data collecting operations: (A) testing and interviewing during the ten-week summer ses-

* The research reported herein was performed pursuant to a contract with the United States Office of Education, Department of Health, Education, and Welfare. Cooperative Research Project No. 715.

[1] Announcement of Summer Science Training Program for High-Ability Secondary School Students, NSF, 1959.

[2] National Science Foundation Programs for Education in the Sciences. NSF Pub. No. 59-6, NSF, Washington 25, D. C.

[3] "Career Development of Scientists: An Overlapping Longitudinal Study," U. S. Office of Education Cooperative Research Project No. 436. W. W. Cooley, Principal Investigator. Harvard University, Sept. 1959, Mimeographed.

sion primarily to determine student change during the program and also to secure information on potential "future scientists"; (B) follow-up questionnaires and interviews during the following school year to study the long-term summer's effects. Before considering the results of our analysis, an outline of the collection operations and the instruments used will be helpful to the reader.

OBSERVATIONAL PROCEDURES

Pre-test Battery: The following instruments were administered during the first two days of the 1959 summer program:

1. STEP Science, Form 1A (Sequential Test of Educational Progress published by Educational Testing Service, Princeton, N. J.)
2. STEP Mathematics, Form 1A (Educational Testing Service)
3. Facts About Science Test (Educational Testing Service, still in experimental form, Referred to below as FAS)
4. Career Plans Questionnaire (Prepared by this research project)

During the ten-week program, one of the investigators visited classes, talked informally with students and teachers, and visited the students while they were working in university and industrial laboratories, interviewing both the students and the cooperating scientists.

Post-test Battery: The following instruments were administered during the next to the last day of the ten-week program:

1. STEP Science, Form 1B (to assess student gain in such abilities as screening hypotheses, interpreting data, quantitative reasoning, etc.)
2. STEP Mathematics, Form 1B (to assess student gain in mathematical literacy)
3. Facts About Science Test (to assess student change in perceptions of science and scientists)
4. Post Questionnaire (covering effects which summer program may have had on college career plans)

Environmental and Personality Attributes: In an effort to provide additional information about high school students who may be contemplating careers in science, we included in the pre-test battery a number of instruments which had been administered to about 200 students of the same age group as part of the Scientific Careers Study. This made possible comparisons of interest, temperament, and general background information.

1. Guilford-Zimmerman Temperament Survey (published by the Sheridan Supply Co., Beverly Hills, Calif.)
2. Kuder Preference Record—Vocational, Form CM (published by Science Research Associates, Chicago, Ill.)
3. General Questionnaire (family data, school and personal background)

Follow-up Observations: The follow-up observations included a series of questionnaires and personal interviews in the spring of the following school year. The people contacted included the fifty-five summer participants, their high school science or mathematics teacher, and their parents.

RESULTS AND CONCLUSIONS

A primary conclusion of this investigation is that standardized instruments are finally becoming available for science education research which can detect changes in student behavior in areas other than mastery of the facts and principles of science, and can detect these changes over relatively short periods of time. Such instruments are especially important for evaluating summer science programs, since "coverage" of a particular body of content is sometimes not a major objective, and evaluations must be in terms of operationally defined objectives. Also, the summer program is usually only six or eight weeks in length (seldom more than ten weeks) and such intervals were thought to be too short for statistical evaluations of the type attempted here.

In addition to the development of procedures for effectively executing summer science program evaluations, some specific conclusions and recommendations regarding the Thayer program are possible. Some of the details of the statistical analysis which served as the bases for the following

conclusions are omitted in this report. However, they are presented in the full report,[4] which is being nationally distributed by the Library of Congress to its depository libraries.

The Ten-Week Program: The major changes in student behavior which were observed during the ten-week period involved the student's image of science and scientists. (The t-tests of pupil change on the FAS and STEP tests are reported in Table I.)[5] These are expected results of a program in which student exposure to scientists in action is the primary activity. It gave the students a close look at scientific research, both the menial tasks and the thrill of discovery. Each one is now in a better position to decide "Is science for me?" Also, the timing of this type of program seemed highly appropriate. Coming at the end of eleventh grade, the students are in a better position to make those educational and career decisions required of them during the final year in high school.

The trends in their image of science and scientists were, in general, toward increased realism. The distinction between science and technology became clearer, and the scientist became less awesome. In addition to the t-tests for demonstrating over-all change in their understanding of science and scientists, McNemar's test for correlated frequencies was used to examine changes on individual test items. Table II reports a few of the items showing significant change so that the reader can get some idea of the nature of these observed changes. Each of the three alternative answers to the item is followed by the number of students who selected that alternate in the pretest and (in parenthesis) by the frequencies for the post-test. Below each item is the corresponding four-fold table and the chi square test of change. The letter of the preferred alternate is in parentheses.

TABLE I

TESTS OF THE SIGNIFICANCE OF PUPIL GAIN

Instrument	Pre-test Means	Post-test Means	Std. Er. Diff.	t	p
FAS Total	60.49	63.45	.540	5.48	$p<.0005$
FAS Part I	29.95	31.15	.311	3.86	$p<.0005$
FAS Part II	30.55	32.31	.213	3.82	$p<.0005$
STEP Science	309.65	314.40	1.47	3.23	$p<.005$
STEP Math	308.24	307.64	.853	−.703	not signif.

Another important area of change involved student plans for college and career. The changes in choice of college were toward more liberal arts. The career plans shifted in the direction of increased interest in scientific research and included a new awareness that college teaching was a career in which research was possible.

In terms of increased competence in science and mathematics, the students did change in abilities measured by the STEP Science test which included screening hypotheses, interpreting data, and quantitative reasoning. However, no change was observed in performance on the STEP Mathematics test. There are several reasons for this finding. One was the lack of emphasis on mathematics for all students. Also, after the program was underway we realized that the mathematical experiences which were offered were not consistent with the emphasis in the STEP Mathematics test.

[4] W. W. Cooley and R. D. Bassett, *Evaluation and Follow-up Study of a Summer Science and Mathematics Program for Secondary School Students.* Harvard University, June, 1960, Mimeographed, 110 pages.

[5] We should point out that since no control group was used for the ten-week program, we cannot be absolutely sure observed student changes are directly attributable to the program. However, we are confident that more refined, subsequent investigations will support these preliminary findings since most of the observed changes were significant at the .005 level and the experience was so uniquely related to those changes.

TABLE II

ILLUSTRATIVE CHANGES IN FAS RESPONSES

36. More security risks have been discovered among scientists than among historians because
 (A) a greater number of scientists have been investigated. 36 (45)
 B. scientists are more easily influenced by subversives. 6 (5)
 C. many scientists have been educated abroad. 12 (4)

		Post-test B & C	Post-test A		
Pre-test	A	2	34	36	Chi square = 4.92
	B & C	7	11	18	$.02 < p < .05$
		9	45	54	

40. On his vacation, a scientist is most likely to
 A. visit a scientific exhibit. 12 (4)
 (B) take a trip around the country. 29 (41)
 C. study a different branch of science. 12 (8)

		Post-test A & C	Post-test B		
Pre-test	B	3	26	29	Chi square = 6.72
	A & C	9	15	24	$.001 < p < .01$
		12	41	53	

34. Of the following, which is the most important characteristic of science?
 A. As many facts as possible are acquired and classified. 21 (7)
 B. Statements are not made unless absolutely true. 1 (3)
 (C) Its own mistakes are discovered and corrected. 32 (44)

		Post-test A & B	Post-test C		
Pre-test	C	1	31	32	Chi square = 8.64
	A & B	9	13	22	$.001 < p < .01$
		10	44	54	

17. It is the duty of all scientists to
 A. tell us how we should use their discoveries. 19 (7)
 (B) report their discoveries in such a way that others may repeat their experiment. 36 (48)
 C. be as economical as possible, since scientific experiments are often very expensive. 0 (0)

		Post-test A & C	Post-test B		
Pre-test	B	2	34	36	Chi square = 7.56
	A & C	5	14	19	$.001 < p < .01$
		7	48	55	

A continuing concern of directors of programs of this type is the problem of selecting the students. Of course similar problems are faced by any attempt to single out "future scientists" for preferred treatment or encouragement through scholarships and honors. Until valid predictors for choice of and success in scientific research are available, the reasonable approach seems to be to select the most able students from among the applicants. In this way the future scientists in the group are aided by the experience, and their able peers who go on into other fields will have a better understanding of science and scientists, certainly desirable outcomes.

Realizing that this is the case, it is important in publicizing such programs to insist that they are for able students, and *not* give the impression that all those selected are future scientists and that those rejected do not look like future scientists. Both impressions are unfortunate and they tend to be conveyed in published descriptions of the programs, if not explicitly, certainly implicitly.

Unfortunately, this investigation was unable to uncover valid predictors of rated student success using multiple regression analysis. The results of correlating three types of variables with related success are presented in Table III. Therefore, it is not possible for us to make confident suggestions for more efficient screening instruments at this time. Several measures of scholastic aptitude and achievement in science and mathematics, together with an interview or questionnaire concerning the extent to which students have voluntarily engaged in home laboratory "research" and extra-class science activities, seem to be the most reasonable approach to selection until improved techniques are devised.

Back to School Follow-up: As far as student changes in school behavior are concerned, improved study habits and greater seriousness of purpose were most frequently reported. The parents and teachers reported no negative effects, but students felt a lack of challenge in the school work and several reported they were bored. That, of course, may not be a result of their previous summer so much as their exposure to a school curriculum designed for less able students.

The non-class science activities did offer some opportunity for individual enrichment, but this was too often left to chance and at times was even impossible. The demands upon the science teacher are frequently too great to allow time for him to give serious attention to these highly able students. This was also reflected in the college and career guidance offered these students. The guidance departments tend not to be offering these talented students what is needed, and the science teacher usually cannot or will not perform guidance functions for students interested in science careers. Yet the students hunger for additional information about col-

TABLE III

Multiple Correlations With Rated Success Criterion

Independent Variables	Mult. R	F ratio	Probability
Ability: STEP Math and Science, FAS, Otis, Coop Math. (5 scores)	.32	1.09	>.05
Temperament: Guilford-Zimmerman Temperament Survey (10 scores)	.28	.44	>.05
Interest: Kuder Preference Record-Vocational	.50	1.66	>.05

lege programs, possible scholarships, future summer science employment, and possible careers. Regardless of where the responsibility lies, the summer programs might seek ways to offer students more guidance information. At Thayer, for instance, a few of the evening sessions might have been devoted to general problems of college admissions, different types of colleges and technical schools, available scholarship aid, etc. Bringing in some college admissions people would be helpful for such sessions. The students were ably shown what scientists do, but more time could well be spent on how to get there.

The follow-up reactions of scientists, students, teachers and parents indicated an overwhelming vote of confidence for the program as it exists. However, a few criticisms were voiced. The most frequent recommendation was for improved communication. Before, during and after the program this seemed to be a major difficulty. Parents and teachers would have liked more information about the program, how their son or student did, etc. Parents and school personnel were extended invitations to attend the final day symposium, where student papers were read, but many could not take advantage of this opportunity. No direct attempt was made to contact the science and mathematics teachers following the summer program. The scientists also wished for more information before the students arrived for laboratory work.

Determining who wants and needs more information about such programs, and how to communicate this to them is indeed a difficult problem. The "back to school" situation would be highly improved and the program would have much greater and broader impact if this communication problem could be solved.

Comparisons with Peer Groups: The fact that the Thayer participants could be compared to college bound students of the same age and geographic region who are subjects of the Scientific Careers Study (SCS) was advantageous to both investigations. The science : non-science trends in interest, temperament and certain questionnaire responses which had been observed in the SCS were cross-validated by the Thayer results. The operation of personality determinants in the movement toward scientific careers is especially evident in the interest-temperament discriminant function.[6] Further follow-up of these students will reveal what confidence we can have in these findings.

One important relationship evident in the SCS comparisons is the high socio-economic status of the families of the summer program participants. This tendency was also observed by another investigation of similar programs.[7] The probable reason is that less fortunate students must have some summer income if they expect to go on to college. Some scholarships were awarded at the end of the program to deserving students, but this seemed insufficient to attract students of lower income families. The science teachers interviewed seemed to feel that a stipend of one or two hundred dollars would have made possible the participation of many able students who otherwise exclude themselves because of financial need. The problem of whether such stipends can and should be made available depending on need, and how to determine that need, is not easily solved.

Further Research: Two related research efforts have already emerged from this investigation. The results of the summer testing indicated the promise of the Facts About Science test, but an improved instrument seemed necessary. We are therefore developing here at the Harvard Graduate School of Education a new instrument, the Test on Understanding Science, which will attempt to measure student perceptions

[6] Further information regarding this analysis can be obtained by writing William W. Cooley, 7 Kirkland St., Cambridge 38, Mass.

[7] Science Research Associates. "Evaluation of the 1959 NSF Summer Science Training Program for Secondary School Students: *Report No. 2. Contract NSF-C115.*" Chicago, Ill., February, 1960, Mimeographed.

of science and scientists. This test is receiving a nationwide try-out during the 1960–1961 school year.

The other research activity stimulated by this investigation is an exploration of the role and utilization of a consultant who would assist schools in providing follow-up activities and personnel services for similar talented students. The problem is to see whether or not it is possible to close somewhat the communication and guidance gap noted above, and if possible, to determine what differences such services make in the "follow-through" impact of the programs.[8]

Future investigations will certainly need to be concerned with the relative merits of various approaches to summer program design. Comparisons in terms of several criteria of student change (such as those used or developed in this investigation) would identify those methods which tend to produce greater change in particular types of behavior. Then if the program designers know what changes are to be emphasized, evidence will be available for deciding on procedural emphasis.

Our own position is that the Thayer program did a creditable job, both in deciding which objectives were important to emphasize and in devising procedures for accomplishing their purposes. The Thayer approach can be highly recommended to programs held in areas where ample research opportunities are available. If the primary intent is to unload more science facts and principles, then other procedures would be more suitable. However, such an objective is inconsistent with the stated purposes of the National Science Foundation programs, which suggest that these programs provide experiences not normally available in the high school, and current high school science programs are strong on facts and principles.

In view of the major research evaluations which were conducted for the National Science Foundation during the summer of 1960, it would not be reasonable for us to make elaborate detailed suggestions for further research at this time. When the results of those current evaluations are available, investigators interested in inquiring further into the consequences of this new educational innovation will be able to build on those more recent efforts, in addition to the findings reported herein. Other discussions of summer programs, evaluations, and plans for research, can be found in the bibliography below.

[8] This study is being conducted by Robert D. Bassett, Harvard Graduate School of Education.

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THE READABILITY OF COLLEGE GENERAL BIOLOGY TEXTBOOKS

ALEXANDER G. MAJOR

State University College of Education at Potsdam, Potsdam, New York

AND

ALFRED T. COLLETTE

Syracuse University, Syracuse, New York

One of the major difficulties encountered by liberal arts students who are not likely to major in any of the biological sciences is their inability to adequately understand the reading material of general biology. Freshman students, in particular, complain that the context of college biology textbooks is difficult to comprehend. If their complaint is valid, we are faced with the problem of textbooks failing to serve as an adequate tool in the study of biology.

The basic purpose of a recent study by Major [9] was to determine whether there is any significant evidence that the difficulties encountered by these students in the study of biology are at least partly due to their inability to adequately understand the assigned reading materials. The investigation was accordingly two-fold. It was designed to determine whether the currently-used and preferred college general biology textbooks are written within the estimated reading comprehension level of college freshman students. Secondly, it was designed to determine the manner in which the readability elements of written material should be altered to achieve maximal comprehension of biological concepts and principles. This report is concerned with the first of these two aspects of the problem.

Since the reported studies on the readability of science textbooks have been directed toward the elementary and secondary levels of education, it was necessary to conduct this investigation in three related phases. The first phase is concerned with the readability elements of vocabulary load and concept load in a biology passage. The second phase is concerned with the extent to which each of the most extensively-used and preferred biology textbooks is written within the reading comprehension level of college freshman students. The readability elements of number of syllables per one hundred words and the average number of words per sentence are the variables which were investigated in the third phase.

The scope of the study was limited to the readability of biology reading material at the college freshman level of reading ability. The population under consideration was limited to liberal arts students who were not likely to major in any of the biological sciences, and who may or may not have had previous formal experiences in biology at the high school level. From among the several factors which contribute to an adequate understanding of a textbook, this study was further limited to a consideration of those variables which can be used as predictors of readability, and which are incorporated into and quantitatively measured by readability formulas.

The five per cent level of confidence was

selected for the first and third phases of the study. If a difference in comprehension could occur by chance more than five times out of one hundred in a common normal population, it was not considered significant. If significant, the difference was probably due to the experimental conditions and could occur by chance at most five times out of one hundred.

IMPORTANCE OF TEXTBOOK PREPARATION AND SELECTION

A review of the literature on readability reveals a growing concern regarding the importance of basic textbooks which are written within the reading comprehension level of the students for whom they are intended.

The Committee on Science Education referred to the importance of textbook selection in the Forty-sixth Yearbook of the National Society for the Study of Education, as follows:

> In general, what seems likely to prove most satisfactory is to select a basic textbook that provides a good general outline of the course and the primary text materials which all the classes may be expected to study and then to supplement this foundational material with a variety of materials from other textbooks, periodicals, and reference words. ([10], p. 48)

Bailey of the Princeton University Press made the following comments regarding the purposes of scientific books:

> . . . when a book is written and published, it becomes a tool. It may be valued for the facts it contains, for the interpretations it presents, for the clarity of its exposition for beginners, or for the validity and enthusiasm with which it presents the results of science to the public. ([1], p. 3

In the first of a series of five articles on readability sponsored by the National Conference on Research in English, Dale, the chairman of the committee, and Chall stated:

> Since reading is still the chief means whereby persons gain information, skills, and entertainment, the effectiveness with which books, newspapers, magazines, and pamphlets convey this information remains an important problem. . . . Since adult education is often that of relating a man to a book—the book must fit the man if any education is to take place. In other words, the book must be readable. ([4], p. 19)

Lorge [8], one of the more recent authors of readability formulas, approaches the problem of readability with the following analysis:

> What a person understands of the material he reads depends upon his general reading ability and the readability of the text he is reading. His reading ability, moreover, depends upon his intelligence, education, environment, and upon his interest and purpose of reading. The readability of a text depends upon the kind and number of ideas it expresses, the vocabulary and its style, and upon format and typography. (p. 404)

He further discusses the concept of reading comprehension as:

> Reading comprehension must be viewed as the interaction between reading ability and readability. Reading ability can usually be estimated by a person's success with an adequate reading test. Readability, however, must be measured in terms of the success that large numbers of persons have in comprehending the text. (p. 404)

As to text selection, Lorge states:

> Teachers of adults, or indeed, any person choosing texts for specific audiences, might give a reading test to a sample of adults to determine the average reading score (as well as the range of such scores). They then could choose texts within the demonstrated range of comprehension of such adults. (pp. 407–8)

These observations, and many more could be cited, leave little doubt as to the importance of textbook preparation and selection appropriate to the reading ability or grade level of the students for whom they are intended. If we further consider the range of reading abilities that exists at any grade level, the problem of textbook preparation and selection which can be comprehended to attain the objectives of biology instruction becomes increasingly significant. We must assume, therefore, that the failure to communicate effectively basic concepts and principles can only lead to frustrations which interfere with the development of favorable interests, attitudes, and appreciations toward the immediate and continued study of biology.

Curtis, who has reported numerous studies on the readability of high school science

textbooks, recently published fourteen basic principles of science teaching. If the readability of a textbook is beyond the reading ability of the students for whom it is intended, at least four of these principles are violated. These are: ([3], pp. 55–9)

1. The stated objectives of any science course are appropriate only if the means by which they can be implemented have already been devised, or can, with reasonable certainty, be invented.
2. The achieving of every objective of science must begin with the building of understandings.
3. In harmony with the democratic conception of education, every individual is entitled to his just share of attention and effort directed toward developing his maximal potentialities.
4. Since, in learning as in practically every other endeavor, an individual's most valuable assets are time and energy, the learning experiences should be planned to achieve the desired goals with the maximum economy of time and effort.

There is accordingly little comfort in the probability that the fundamental tool of written communication, the textbook, does not:

1. appropriately implement the stated objectives.
2. adequately achieve the desired understandings of biology.
3. develop the maximal potentialities of our students.
4. effectively and efficiently achieve the desired goals.

READABILITY OF MOST EXTENSIVELY-USED AND PREFERRED TEXTBOOKS

Procedure

In order to determine which of the currently available textbooks were most extensively-used during the academic year 1953–54, a questionnaire was sent to 168 colleges throughout the nation. Provisions were made for indication of textbook currently used, textbook preferred, and for comments. The number sent to each state was in proportion to the number of colleges in that state with an enrollment up to three thousand students. Institutions with larger enrollments were excluded since they are probably organized on the basis of separate zoology and botany departments.

Approximately eighty per cent or 136 of the questionnaires were returned. Of this number 112 taught general biology or its equivalent; 101 used a basic biology textbook, and eleven used a separate zoology and botany textbook. The returns for the ten most extensively-used and preferred textbooks are summarized in Table I.

TABLE I

SUMMARY OF NATIONWIDE SURVEY OF THE TEN COLLEGE BIOLOGY TEXTBOOKS MOST EXTENSIVELY USED AND PREFERRED *

Text (1)	Currently Used by (2)	Preferred by (3)
A	14	15
B	14	8
C	11	7
D	8	11
E	7	8
F	7	6
G	7	5
H	7	3
I	4	3
J	0	7

* Listed alphabetically according to author's name in bibliography (References 11–20).

These represent seventy-nine per cent of the twenty-two general biology textbooks reported in use, and seventy-seven per cent of the textbooks which were preferred. If no preference or contemplated change was specified on the replies, it was assumed that the textbook currently used was preferred and would again be used during 1954–55.

Flesch's reading ease formula [6, 7] of syllable count and average sentence length was selected for this study. This formula was preferred because of the potential effectiveness and efficiency of syllable count and sentence length when applied to biology reading material. ([9], pp. 15–6)

In determining the readability score for each textbook, one hundred word samples were taken from every tenth page. The method of obtaining the number of syllables per one hundred words (syllable index) and the average number of words per sentence (average sentence length) was in accordance with the procedure outlined by

Flesch. ([6], pp. 1–6) The resulting "reading ease" score, calculated from the syllable index and average sentence length, is referred to in this study as the "readability" score. The interpretation of the "readability" score (Table II), is, therefore, identical with Flesch's interpretation of "reading ease" score. ([6], pp. 43–5)

TABLE II
INTERPRETATION OF READABILITY DATA[a]

Readability Score (1)	Description of Style (2)	Grade Level Estimate[b] (3)	Magazine Typically Employing Style (4)	Syllables per 100 Words (5)	Average Sentence Length (6)
90–100	Very Easy	5th grade	Comics	123 or less	8 or less
80–90	Easy	6th grade	Pulp-fiction	131	11
70–80	Fairly Easy	7th grade	Slick-fiction	139	14
60–70	Standard	8th & 9th grade	Digests, Mass non-fiction	147	17
50–60	Fairly Difficult	10th-12th grade	Quality Harper's, Atlantic	155	21
30–50	Difficult	13th-16th grade (College)	Academic, Scholarly	167	25
0–30	Very Difficult	College graduate	Scientific, Professional	192 or more	29 or more

[a] Rudolph Flesch, "A New Readability Yardstick," *Journal of Applied Psychology* (June, 1948), 230.

[b] Rudolf Flesch, *How to Test Readability.* New York, Harper & Brothers, 1951, p. 43.

TABLE III
INTERPRETATION OF HUMAN INTEREST DATA*

Human Interest Score (1)	Description of Style (2)	Typical Magazine (3)	Percentage of Personal Words (4)	Percentage of Personal Sentences (5)
60–100	Dramatic	Fiction	17 or more	58 or more
40–60	Highly interesting	*New Yorker*	10	43
20–40	Interesting	Digests	7	15
10–20	Mildly interesting	Trade	4	5
0–10	Dull	Scientific	2 or less	0

* Rudolf Flesch, *How to Test Readability.* New York, Harper & Brothers, 1951, p. 10.

TABLE IV
SUMMARY OF HUMAN INTEREST DATA FOR SAMPLES FROM MOST EXTENSIVELY-USED AND PREFERRED COLLEGE BIOLOGY TEXTBOOKS[a]

Text (1)	Average Human Interest Score of Textbook[b] (2)	Per-Cent of Personal Words (3)	Per-Cent of Personal Sentences (4)
A	1.56	.43	0
B	.98	.27	0
C	1.02	.28	0
D	3.60	.99	0
E	.62	.17	0
F	1.16	.32	0
G	.22	.06	0
H	2.73	.75	0
I	3.53	.97	0
J	2.27	.63	0

[a] See Table III for interpretation of data.

[b] Employing Flesch's human interest formula ([6], p. 8).

According to Flesch, "readability" includes the two components, "reading ease" and "human interest." The "human interest" score (How interesting is it?) ([6], pp. 6–10) for each of the ten biology textbooks is included in Table IV, and interpreted in Table III, to demonstrate that this factor is not an achieved component of biology textbooks. Flesch states that this lack is generally true for all textbooks. ([5], p. 148)

4. The per cent of samples above the "fairly difficult" category of readability, the grade level immediately below the assumed norm of college freshman students.
5. The per cent of samples above the lower quartile of the "difficult" category which is the approximate grade level of college freshman students.
6. The range of the readability scores of the samples.

A single "average" readability score was calculated for each textbook, and is included in column 4 of Table V. This is the

TABLE V

SUMMARY OF READABILITY DATA FOR SAMPLES FROM MOST EXTENSIVELY USED AND PREFERRED COLLEGE BIOLOGY TEXTBOOKS[a]

Text (1)	Mean Readability of Samples[b] (2)	Standard Deviation (3)	Average Readability of Textbook[c] (4)	Average Syllable Index[d] (5)	Average Sentence Length[e] (6)	Per cent of Samples Above Fairly Difficult Category[b] (7)	Per cent of Samples Above Lower Quartile of Difficult Category[b] (8)
A	45.18	11.65	46.38	164	21.39	61.3	46.8
B	44.45	12.40	44.41	169	19.16	61.8	47.3
C	45.19	12.90	45.72	168	18.71	60.4	50.0
D	48.74	12.70	50.16	165	16.83	53.6	39.1
E	45.98	11.10	47.64	163	20.98	56.3	46.9
F	47.25	10.87	47.79	164	20.00	59.3	42.4
G	39.57	10.65	39.49	176	18.18	84.7	70.8
H	48.10	11.85	48.49	164	19.31	59.0	35.6
I	48.33	8.95	49.26	164	18.55	56.3	32.8
J	42.39	11.05	42.13	175	16.41	78.1	59.4

[a] See Table II for interpretation of data.
[b] Calculated from distribution in Table VI.
[c] Employing Flesch's reading-ease formula.[1]
[d] Total number of syllables divided by number of samples.
[e] Total number of words divided by total number of sentences.
[1] Rudolf F. Flesch, *How to Test Readability.* New York, Harper & Brothers, 1951, p. 4.

Instead of reporting a single average readability score for an entire book, the syllable index, average sentence length, and readability score were determined for each sample. ([9], Tables 17–26, pp. 43–52) In addition, the mean readability score and the standard deviation of the samples from each textbook were calculated, and are included in Table V. By following this procedure, the following data were obtained for each of the ten textbooks:

1. The mean readability score of the samples.
2. The distribution of the readability scores of the samples.
3. The standard deviation of the readability scores of the samples.

method generally used for determining the readability of written materials. ([6], pp. 1–6)

INTERPRETATION

The summary of readability data in Table V reveals that the mean or average readability scores, average syllable indexes, and average sentence lengths for eight of the textbooks occupy very nearly the same respective loci in Table II. These similarities suggest a characteristic style employed by authors of general biology textbooks.

Criterion of Syllable Index

The average syllable indexes (column 5) for eight of the textbooks range from 163 to 169. These indexes are very nearly equal to 167 which is the median of the difficult category (Table II). This is probably the locus between the fourteenth or college sophomore grade and the fifteenth or college junior grade levels of reading ability. The indexes for texts G and J are 176 and 175, respectively, which are classified in the upper half of the difficult category.

In the first and third phases of this study ([9], pp. 18–38, 59–74), it was found that the average readability of biology written material should not be written above the twelfth grade level for students of "above average" ability. For freshman students of "average" ability, the syllable index should be approximately 155. This may be estimated as the locus of eleventh grade reading ability. Significant differences were not obtained for students with "below average" ability. There are probably other factors in addition to that of vocabulary and concept loads which influence their understanding of biology reading material. These probable other factors are beyond the scope of the conditions which were incorporated into the study.

On the basis of the syllable index criterion, the readability of each of the ten most extensively-used and preferred general biology textbooks is too high for liberal arts freshman students. These students will probably encounter reading difficulty with the high scientific and non-scientific vocabulary load, concept load, or both in all of these textbooks.

The similarity of average syllable indexes may be due to the universal language of scientific expressions and descriptions which have evolved among biologists. These are the individuals who determine the success of a textbook by their approval and adoptions. This observation is in agreement with Bates' comment that: "As it is now, all books on science get about the same treatment, regardless of the audience at which the book is directed." ([2], p. 407)

Criterion of Sentence Length

Whereas the element of average syllable index for each of the textbooks tends to decrease the readability, the element of average sentence length tends to increase the readability. The average sentence lengths range from 16.41 for text J to 21.39 for text A. The former is very nearly equal to the mean of seventeen words per sentence which is characteristic of eighth to ninth grade reading material. The latter is equal to the mean of tenth to twelfth grade material. This factor of relatively short sentence length further indicates that the estimated difficulty of the analyzed textbooks is due to a high syllable index.

Mean Readability

The mean readability of the distributions is listed in column 2 of Table V. Small but insignificant differences may be noted in the mean readability and average readability scores. These are due to methods of determination.

The locus of the mean readability for eight of the textbooks is in the lower quartile of the difficult category. This is approximately the thirteenth or college freshman grade level. The mean of Text J is in the second quartile, and the mean of text G is at the mean of the difficult category. The second quartile may e interpreted as the fourteenth or college sophomore grade level.

Distribution of Readability Scores

The distribution of readability scores for the samples from each textbook is summarized in Table VI. These distributions and the standard deviations in column 3 of Table V demonstrate differences among the books which the ten mean or average readability scores do not reveal. The most significant differences to be noted are the

TABLE VI

DISTRIBUTION OF READABILITY SCORES FOR SAMPLES FROM MOST EXTENSIVELY-USED AND PREFERRED COLLEGE BIOLOGY TEXTBOOKS

	Textbooks									
Readability	A	B	C	D	E	F	G	H	I	J
75–79				1				1		1
70–74	1			2		1				
65–69	2		5	7	4	3		7	2	1
60–64	6	7	4	6	6	4	2	5	4	3
55–59	7	7	6	5	6	7	5	6	12	2
50–54	13	7	8	11	12	9	4	11	10	7
45–49	12*	8*	6*	10*	6*	10*	10	17*	15*	12
40–44	12	9	9	10	16	14	19	14	11	12*
35–39	10	5	8	8	6	2	10*	4	7	11
30–34	7	3	5	5	4	6	10	3	2	9
25–29	4	3	4	2	2	2	7	2		4
20–24	1	6	1	2	2	1	2	1	1	
15–19	2		2				1	2		2
10–14							2			
5–9										
0–4										

* Interval in which mean of samples is located.

per cent of samples which exceed the reading comprehension level of average and above average freshman students.

According to column 8 in Table V, above average students are likely to experience reading comprehension difficulty with assignments which range from 32.8 per cent for Text I to 70.8 per cent for text G. Average students are likely to experience difficulty with assignments which range from 53.6 per cent for text D to 84.7 per cent for text G. (column 7) These percentages are probably too high if the textbooks are to serve as effective and efficient tools in the study of general biology at the college freshman level.

The readability data obtained from every tenth page of a textbook reveals that difficult passages occur as frequently at the beginning as in any other section. ([9], tables 17–26, pp. 43–52). This observation suggests that the probable reading ability of beginning students was not considered in the preparation of these textbooks.

CONCLUSIONS

On the basis of Flesch's interpretation of readability data and the findings of the first and third phases of this study, the most frequently-used and preferred general biology textbooks are written beyond the reading comprehension level of college freshman students. This report on the second phase supports the following conclusions:

1. All of the currently most frequently-used and preferred college general biology textbooks are written at least one grade level above the reading comprehension level of college freshman students.
   a. The average readability of general biology textbooks are written at least one grade level above the reading comprehension level of college freshman students of "above average" ability.
   b. The average readability of general biology textbooks are written at least two grade levels above the reading comprehension level of college freshman students of "average" ability.
2. The reduced readability of general biology textbooks is due, primarily, to a high syllable index.
   a. A high syllable index is an objective measure of a high scientific and non-scientific vocabulary load, concept load, or both.
3. The relatively uniform syllable index, and hence readability, among general biology textbooks suggests the probable evolution of a characteristic style employed by authors.
4. Difficult passages occur as frequently at the beginning of a textbook as in any other section.
5. The percentage of difficult reading assignments in all of the textbooks is probably too high if they are to serve as effective and efficient tools in the study of general biology at the college freshman level.

RECOMMENDATIONS

1. Instructors of general biology should test the readability of assignments and adapt their instructional procedures accordingly. If an effective and efficient method of estimating readability is employed, the required time of analysis is not prohibitive. Flesch states that his method should not take more than two and one-half minutes to test a one hundred word sample to determine both the "reading ease" and "human interest" scores ([6], p. 10). Students may be referred to more readable parts of textbooks, or more effective class procedures could supplement difficult reading assignments.

2. When existing biology textbooks are revised, difficult sections should be made more readable. This revision should also be followed with teacher-prepared reading materials.

3. Future first-edition biology textbooks should be written at the reading comprehension level of the students for whom they are intended.

4. If biology is now being taught in the freshman year, it would be advisable to move the course into a later year unless or until a textbook is available with a readability appropriate for freshman students.

5. Readability should be included as one of the basic criteria in textbook selection.

LIMITATIONS OF STUDY

It will be recalled that this study was limited to a consideration of those variables which can be used as predictors of readability, and which are incorporated into and quantitatively measured by readability formulas. There are other variables which may contribute to ease of reading and understanding. These include the more tangible variables such as the effect of typography, paper, the amount and quality of light under which a page is read, and the use of illustrations.

There are other less tangible aspects of written material which are at most only partly or indirectly measured by readability formulas. There is some evidence that a strong interest may motivate one to read material that would normally be far beyond his reading comprehension level. Organization of material, choice of effective words, and some aspects of style of writing are additional examples of the art of writing which do not lend themselves readily to measurement by readability formulas.

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DO YOU CONDUCT YOUR SCIENCE LABORATORY EFFICIENTLY?

MARC A. SHAMPO
Duquesne University, Pittsburgh 19, Pennsylvania

ARE you working too hard? How often have you seen this question on various advertisements that you have received in the mail? Have you read them carefully or have you just glanced at them and then thrown them away? If you have read with care you have probably noticed that they attempt to point out how your work can be easier and more productive through increased efficiency. Efficiency, work output divided by work input, is most important in every phase of our life. The science teacher is well aware of the fact that in some experiments measuring to the nth degree is wasteful and inefficient while in others it is imperative. Efficiency is one concept that we attempt to teach our students. Beside realizing academic efficiency in the science courses, it is important to have administrative efficiency while directing the laboratory exercises. It is with this latter in mind that this paper is written.

One of the most important functions of the secondary school science teacher is to offer opportunities for the student to conduct experiments in the laboratory. There is no question as to the value of such work. Where else can the individual develop and practice the skills that are so fundamental to science? However, this unique and worthwhile opportunity with its consequences can be very burdensome to the teacher. Science teachers do have to work hard in any laboratory, but if they organize the work and orient the students properly, everyone can benefit. How can the science teacher conduct a more efficient laboratory activity? The writer would like to share some of the experiences that he has found to be worthwhile. It is possible that this could help two groups of science teachers; one, the experienced teacher can check on what he has been doing and reevaluate his work in the light of the present suggestions, and two, the inexperienced or beginning teacher can utilize the suggestions as a starting point for his future work and planning.

Laboratory work differs much in the manner of organization and supervision depending primarily upon the size of the school, laboratory, number of students, amount and types of equipment and the individual classroom teacher. However, there are some general suggestions that are helpful to use as guides in any laboratory work.

In a small high school with only a teacher demonstration desk where experiments are conducted around this desk by the teacher or the students, supervision is not much of a problem. The teacher is always present, demonstrating, checking, and evaluating. This type of laboratory supervision will not be discussed here because it presents only minor problems. The real test of organization and orientation is in the larger school with more students, more equipment, and

more supplies. Here, as each student may have his own individual laboratory desk, the teacher cannot possibly supervise, check, and evaluate all of the students at any one time. It is in this environment that efficient administration is most important. It is in this environment that some suggestions to the new and inexperienced teacher may help immeasureably. The writer is more experienced with the administration of work in a chemistry laboratory and therefore all suggestions are subsequently directed toward that specific area. However, efficient laboratory administration is a skill that the teacher can transfer to any laboratory science with slight modifications necessary only in specifics.

To organize and conduct laboratory activities efficiently, it is necessary for the teacher to consider:

1. The introduction and orientation of laboratory work to the class.
2. The ultimate values as a direct result of this organization.

Some attention to each is necessary and intelligent consideration of both points will most certainly improve the overall efficiency of your laboratory work.

It is important that you spend specific class time on the introduction and orientation of laboratory work. If you, as the teacher, move slowly, deliberately, and thoroughly on this initial phase, the foundation for all future laboratory work will be properly set. If this aspect is well done, your class can gain momentum as the work progresses because the classroom atmosphere will be of a more congenial nature, less confusing for the students, and less burdensome to the teacher.

Your students must spend time learning the names of the pieces of the most commonly used apparatus. This may be accomplished in the laboratory by the handling of the actual equipment with or without supplementation using two dimensional drawings on mimeographed sheets, flash cards, or some other appropriate technique.

Next, it is important that the students practice setting up and disassembling apparatus. This should include insertion of glass tubing and thistle tubes in rubber stoppers of different sizes. It may appear at first that it is a somewhat artificial procedure to do these exercises without actual experimentation and it would seem likely that this could be learned along with the regular experiments. However, it appears that the two are mutually exclusive and this initial skill must be developed apart from the specific knowledges in each experiment. The future experiments can subsequently reinforce this skill. The time spent on proper orientation is only a small fraction of the year's work, and it is imperative that the proper fundamental skills be developed in every student. The teacher should use the gifted or the mechanically inclined to help supervise these preliminary activities in order to be sure that everyone can assemble and disassemble the basic types of laboratory setups. It may even be worthwhile to have a number of mimeographed pictures of the basic equipment setups to supplement the work. This knowledge and skill on the part of the student gives him confidence and adds to his achievement later on.

The purposes and procedures of laboratory activities and experiments should be carefully explained to the class at the beginning of the year. This should include not only the unique values and contributions of the laboratory but also, the individual student's duties, and the grading procedures.

Grading of student laboratory work (not the quality of the writeups, which is another consideration) of the routine duties is important. It is worthwhile to grade the student on the cleanliness and organization of the apparatus (especially glassware). This insures a much tidier laboratory and also teaches the student some of the valuable work habits that are so necessary for successful work later on. The students may or may not be assigned to specific drawers or cabinets. If they are assigned, this

checkup is much easier to accomplish. A very effective method for grading the individual is to compile a rating sheet with the appropriate criteria and ask three students to check all apparatus and decide upon a suitable grade. This type of grading procedure may be carried out at specified times. It is much more effective, however, if grades are given frequently and at unannounced times.

Another point in realizing an orderly and effective laboratory is to assign specific routine duties to be carried out at the beginning and at the end of each laboratory session. These duties must be explained carefully during the orientation period and the execution should be checked frequently at the beginning of the year. A good procedure is to name, number, and explain the specific duties. A typed copy should be placed on the bulletin board in the laboratory. A duty roster of the names of the students with the duty number following for a weekly or bi-weekly period should also be placed on the bulletin board. It is well to assign two students to each duty. This takes into consideration absences and insures that at least one student will be responsible for the assigned duty. The function of these duties will teach responsibility to the student as well as contribute to the overall cleanliness and efficiency of the laboratory.

It might be well at this point to enumerate the specific duties that seem to be effective for an ordinary laboratory of about 32 students.

These duties are beside the laboratory experiment that each student must conduct and the routine cleaning of each individual work bench. The duties listed are merely examples and since each laboratory may be designed in a slightly different manner, teacher preferences and variations may also affect these duties.

If the student is familiar with the apparatus, he can devote more time to the principal understandings and extra skills required in the ensuing experiments, and if the routine administrative tasks are well taken care of, the teacher can devote more time to academic achievement during each experiment. In general, everyone can benefit all year long by a more complete and efficient use of the laboratory organization.

There are four general values, beside any direct academic value, that are realized by this particular type of laboratory organization.

1. Routine experiments from the regular laboratory book will proceed much smoother in regard to starting experiment and cleaning up when completed.

Duty Number	Name of Duty	What Student Should Do
1.	Solutions	Check with instructor about keeping the small individual reagent bottles of acids and bases filled.
2.	Cleanup supervision	Check to see if water or acid is on the floor, drains are clear of paper, matches, and debris, water faucets turned off, and desk tops washed and cleaned. If anything is not correct *mention* to the offending student.
3.	Keys beginning of the period	Obtain master key from the teacher, open the key closet, wait a few minutes for all students to get their individual keys, lock closet and return master key to the teacher.
4.	Keys end of period	When "cleanup" is called, obtain master key from the teacher, open key closet and see that the students place their keys on the proper hooks, when all keys are returned, lock the closet and return the master key to the instructor.
5.	Special equipment	Clean the area where the special equipment is placed, check to see if all pieces are clean and turned in, replace in an orderly fashion.
6.	Hood checking	Check to see if the hoods are clean and free of equipment.
7.	General supervision	See that all duties are being carefully carried out and report any gross negligence to the teacher.
8.	Supply room	Special directions are posted in the supply room.

2. Independent experiments or variations from the regular work will be accomplished more effectively. This is especially important when these are rather long and require more than one period to finish. Examples of these would include experiments in qualitative and quantitative analysis, organic chemistry, and consumer chemistry.
3. Teacher substitutes can plan and conduct laboratory work and need not just be baby sitters, since the students are more efficient under the planned organization type of laboratory work.
4. In a science teacher's work, many physical hazards and dangers are always present. A well organized laboratory will reduce these dangers and thus reduce the possibility of resulting damage suits. A well organized laboratory will show evidence of the effects of a "prudent" person who has foreseen the possibilities of "negligence" in a future tort case.

In summary, it would be well for the experienced science teacher to reevaluate his present laboratory administration and the inexperienced science teacher to consider future organization of laboratory work carefully. The suggestions given have been:

1. A slow deliberate introduction to laboratory work with proper student orientation to names and use of equipment and laboratory procedures will increase the effectiveness.
2. Use of duty roster will teach responsibility and will keep the laboratory clean and orderly and allow the teacher more time to teach.
3. Use of grades for the routine laboratory work and not only for the laboratory experiment writeups will add to the efficiency of the laboratory.
4. A realization of other values from a well organized laboratory include more efficiency during the routine experiments, better working atmosphere for independent work or digression to enrich your program, more efficient use of substitute teachers when needed, and last, evidence of planning and preparation in a possible tort liability suit.

Efficient laboratory administration does not happen—it must be planned—and you, as a science teacher, must consider it carefully along with the subject matter content of each experiment.

THE DISCUSSION GROUP METHOD IN SCIENCE EDUCATION

John J. Montean
University of Rochester, Rochester, New York

During the last several decades the development of critical thinking has been increasingly emphasized as a primary objective of education. Parallel to this has been the development, especially in education, of the use of group methods for instruction. However, in examining the literature relating to group methods as a teaching technique, one is impressed with the paucity of studies in the area of science education at the college level. These last few years have been more fruitful in this regard and a number of studies have been reported. These indicate a growing interest on the part of educators to determine the efficacy of group methods as an instructional device in achieving some of the objectives of science education.

During the fall semester of the school year 1957–8, an experiment was conducted at Auburn Community College to study the effectiveness of the use of discussion groups as a means of increasing the ability to think critically. The contexts within which critical thinking was studied were pre-engineering general chemistry and general education physical science. Both of these courses consisted of normally enrolled freshman students.

The experiment was, in general, an analysis of pre- and post-test scores achieved by the individual involved on the Test of critical Thinking, Form A.

NATURE OF THE TEST

The Test of Critical Thinking, Form A was developed by the Committee on Measurement and Evaluation of the American Council on Education for use in those group situations where there exists a need to ap-

praise, over a period of time, the development of critical thinking abilities. The Committee in developing this test singled out the problem-solving aspect of critical thinking as the measurable entity. Such traits as the ability to recognize the existence of a problem, to define the problem, to select information pertinent to its solution, to recognize assumptions, to make hypotheses, to draw conclusions from assumptions, hypotheses and pertinent information, to judge the validity of the conclusions and to evaluate the conclusion in life situations were aspects subsumed under problem-solving. The Committee designed this test to measure the ability of college students to demonstrate some of these skills and the test has proven to be reliable for those situations involving group measurement at a pre- and again at a post-testing time.

ORGANIZATION OF THE EXPERIMENTAL CLASSES

The experimental classes were divided into sub-groups of five or six students on the basis of their ACE scores which were obtained during the freshman registration period. It was felt that in this manner each of the sub-groups involved would have approximately the same potential. This also gave each sub-group a composition of individuals of varied backgrounds and talents.

Each of the sub-groups had its own structure with a chairman and a recorder. Since these were on a rotating basis, each individual of the group had the experience of serving both as a chairman and a recorder. The use of a rotating chairman minimized the possibility of any dominating leadership.

Each of the members in both of the experimental classes was given a copy of the semester course outline. This was topically arranged in keeping with the course content indicating each week's assignment and laboratory experiments.

Certain phases or steps generally become evident in the group-discussion process which involved the instructor or the sub-group singly or collectively. The first phase became the responsibility of the instructor in presenting the problems and the essential information. At the beginning of each week, the instructor took part of the first discussion period to present and clarify fundamental principles. Factual material was the responsibility of the student and the instructor did not take the class time to repeat the same. Where factual material was presented, it was deemed necessary to any clarification of principles.

The problem-solving phase of the discussion sessions involved the solving of problems devised by the instructor.

The problems were related to the weekly topical schedule and each member was issued a similar mimeographed copy containing the problems that were to be discussed during the class period. Where possible, the problems were the same or similar in structure to problems illustrated in Questions and Problems in Science by Dressel and Nelson.[1] The number of items was limited by the time of the class period. It was considered important that the group assume the feeling of responsibility for the success of the problems, therefore sufficient time was made available for the groups to solve the problem presented.

ROLE OF THE INSTRUCTOR

While the various groups are solving the various problems through discussion, the instructor moves about the room. As the mature individual, he recognizes those groups that may be in need of some stimulation. If digressions have occurred, the instructor asks questions of the group in order to stimulate the students' responses. These visits to the group tend to give direction and purpose. These also serve the instructor as an evaluative device of the product of the sub-groups' efforts. The relaxed manner of the instructor conveys the necessary permissiveness that is conducive

[1] Questions and Problems in Science Test Item Folio No. 1. Prepared by Paul L. Dressel and Clarence H. Nelson. Published by Cooperative Test Division, Educational Testing Service, Princeton, New Jersey, 1956.

for the individuals to speak freely. This is not to be interpreted as a laissez-faire situation with no leadership.

Discussion may be difficult to obtain in the beginning but gradually with encouragement, the more reticent students begin to voice interest. And as Halverson [2] has indicated, "a great deal of problem solving can be accomplished in an ordinary class period. Encouragement of the participation of all in a group soon develops in each individual a kind of responsibility or allegiance to the group and its success in solving the problems.

The teacher in such a classroom plays many roles. These Halverson [3] has indicated very ably as follows:

TEACHER ROLE

Maintaining Small Groups

The teacher serves in the following ways:

1. *Stimulator Role:* raising of issues, questions, and alternatives. As he moves among the groups listening to their deliberations and plans, the teacher has a responsibility to function as a more mature person.
2. *The Expert Role:* is the authoritative position which the teacher inherits and must fill to satisfy the expectations of most pupils. Nature of the expertness should be restricted to those skills which can be taught and demonstrated. The teacher suggests how to secure information and facts.
3. *The Resource Role:* on matters involving skills which have not been developed or used in a more typical large group or individualistic procedures.
4. *Conscience Role:* (a) to counteract classroom situation involving poor habits in respect to responsibility for work, punctuality, concentration and cooperation.

   (b) To counteract the facts that due to the anonymity of the group, the less close supervision and some confusion and doubt about the whole process may tempt some pupils to evade responsibility, disturb group discussion, or develop a general apathy toward the group, *the teacher* uses close and frequent contact to observe these developments.

   The experience of most teachers is that if a group has been organized around a problem or interest, the group develops its own conscience.
5. *Coordinator Role:* govern the sharing of the sub-groups' activities, learnings and outcomes. Small group operation is only one method of organizing learning experience.

The test for all our proposals for cooperative group work in problem solving is the extent to which they contribute to better learning of facts, attitudes, skills, habits, appreciations and understandings. But each teacher who employs group work to any degree will be motivated to check up *both on the product and the process of such learning procedures.*[4]

SUMMARY

When the test was administered in pre and post situations, it was discovered that the entire population gained in critical thinking ability. There were also gains evident for each of the populations of the two disciplines examined. With the increase in significance of general education in the college curriculum, it is important to know how well some of its goals are being achieved, not only in those courses that are specifically designed for general education but also in the so-called traditional science courses. These courses ought to make a general education contribution. The results of the experiment with the general chemistry population indicates a step in this direction.

The increase in critical thinking ability as evidenced by the results of the study are especially related to gains made by the experimental classes. Since the discussion group procedure was used in these classes, it may be inferred that the use of discussion groups, as a teaching technique, may be used in such disciplines as freshman general chemistry and general education physical science as a means of increasing critical thinking ability.

Another purpose of the investigation was a study of the relationship of mental ability and critical thinking in terms of the acqui-

[2] P. M. Halverson, and W. M. Alexander. *Effective Teaching in Secondary Schools, 1956.* Rinehart and Company, Inc., New York.

[3] *Ibid.* (p. 274).

[4] *Ibid.*

sition of critical thinking ability within the context of discussion group methods. It was established with confidence that students of median and low ability in the experimental classes demonstrated a greater gain in the ability to think critically than did students of similar mental ability in the control classes, as measured by pre- and post-test scores on a Test of Critical Thinking. This comparison of the scores of students who received instruction by the discussion group method and those who received instruction in the traditional climate indicated the gain in the ability to think critically attributable to the teaching technique used.

In examining the results of the disciplines themselves, the students of high ability in the experimental general science demonstrated a significant gain in critical thinking when compared to the performance of students of similar ability in the control class. Since this was not the case with the general chemistry high ability group, it may be assumed that the use of the discussion group method favors the high ability student in the general science context. However, in regard to students of low ability, a significant gain was made in the experimental general chemistry which was not the case with the low ability experimental general science group. Thus, it may be inferred that the use of the discussion group method favors the low ability student in the general chemistry context. These various differences may be related to the nature of the material or course content of general chemistry and general science.

In general, the analysis of the data supports the conclusion that the use of the discussion group method as a means of increasing the ability to think critically favors the student of median and low ability. Since we are all vitally concerned with the development of critical thinking ability in our science teaching, it would seem that the implementation of discussion groups in our teaching would insure the acquisition of this ability by a larger population of our classes.

Another purpose of the investigation was concerned with achievement. This was, in effect, the relationship of the use of the discussion group method and achievement in general chemistry and in general science. In regard to general chemistry, the experimental class made significant gains, and, in general, it may be stated that the use of discussion groups in general chemistry increases the mastery of all phases of subject matter content.

In regard to general science, on the basis of evaluative criteria used, no significant difference was evident on recall-recognition type items. However, on more-understanding type items a significant difference was found in favor of the discussion group experimental class. In general, it may be said that students who received instruction by the discussion group method reached the achievement level obtained by students enrolled in traditional lecture classes.

Therefore, it may be stated with reasonable confidence that students undertaking the study of freshman general chemistry and general science may do so without experiencing loss of achievement in these areas.

The development of critical thinking is a very important objective of science education. In general chemistry and general science, emphasis is placed on reasoning from fundamental principles and interpretation of data in solving problems. Science by the very nature of its materials seems to offer a way to realize this objective.

We need experimentation and research to gather not only evidence regarding the use of discussion groups, but other types of effective instructional techniques as well. The Junior College is primarily a teaching institution and improvement in instructional practice should be encouraged in all areas in order that it achieve its purposes.

A METHOD FOR INSTRUCTING THE NATURE OF THE SCIENTIFIC ENTERPRISE

MORRIS GORAN
Roosevelt University, Chicago, Illinois

THE general education physical science course at Roosevelt University has three objectives: to learn some important theories and facts in the physical sciences; to know the nature of science; and to become introduced to the inter- as well as intra-relationships of science. The first goal is not only traditional but is necessary and vital to the attainment of the other goals. The third goal is exceedingly helpful in motivating students who are reluctant and do not do their best unless they can see the connection between science and their own interests. Also, some of the concepts used to relate are very useful integrators of knowledge. Energy and equilibrium, for example, are presented as relevant in many seemingly-diverse topics.

The second goal is commonly expressed as one variety or another of scientific method. Yet the procedure is only one aspect of what science is all about. There are also such considerations as what makes a scientist, are the aims of science any different than those of other knowledge areas, what does science presuppose, does science offer certainty, and a host of other questions.

The second goal is pursued in both the field and laboratory physical sciences. (The course at Roosevelt University is designed so that the field physical sciences are offered first and the laboratory physical sciences are in the second semester.) A total of approximately 20 characteristics and procedures of science are presented in two semesters.

During the first semester, for example, the necessity for many appropriate evidences to form a rigorous conclusion is one of the 10 characteristics and procedures of science highlighted. In this case, the material about the earth as an astronomical body serves as a vehicle. The fact that the earth is an oblate spheroid, rotates on its axis, and revolves about the sun is learned simultaneously with effective inductive processes. The instructor asks for evidences for earth's sphericity and many responses are given. Each, for they are given individually, the instructor shows to be applicable to the conclusion that the earth is shaped like a banana or a pear. A common student response that the manner in which a ship disappears over the horizon indicates sphericity can be used to indicate any curvature. By the time the brighter students bring forth such evidences as the almost-equal acceleration of gravity at sea-levels throughout the earth's surface, the instructor is ready to emphasize the necessity for many evidences to form a rigorous conclusion.

The point is reaffirmed when asking for the number of evidences which when summed lead to the conclusion. Inevitably, students will introduce evidences for earth curvature (of any kind) and this is the opportunity for the instructor to show that appropriate evidences rather than related-in-some-way evidences must be summed.

Identical classroom techniques can be used in demonstrating the earth's rotation—after the Foucault Pendulum experiment is clarified—and the earth's revolution.

Another of the 10 characteristics or procedures of science highlighted in the first semester of physical science at Roosevelt University is the logical structure of a theory. In our course, this is done in conjunction with theories about the development of the solar system. Students are given six questions with which to analyze theories: What are the basic assumptions or where do we begin? What are the jus-

tifications for the assumptions or why do we start there? What are additional facts and theories adopted or what else is believed? What is the theory? What are facts harmonious with the theory? What are facts not harmonious with the theory?

The first question should show the student the necessity of preliminary beliefs when framing a theory; it should destroy the notion that a theory begins vaguely; it should promote the thought that a theory has a basis in prior knowledge. The second question can introduce the student to the conception that a theory may have only pragmatic tests and that beginnings need not be justified. Beginnings adopted in many theories are often the result of historical circumstance. The third question indicates that other ideas besides the basic one must be used to build a theory. Questions five and six, of course, reveal the balance sheet for acceptance or rejection of a theory.

The second semester of physical science at Roosevelt University highlights 10 characteristics and procedures of science. For example, in the material on matter and energy where the ideal gas laws, Archimedes' principle, Pascal's principle, and Bernouilli's principle are discussed, the idea that science has ideal concepts with no real counterparts in nature is presented. Perfect vacuum, ideal gas, and isolated system are shown to be typical of the many ideals in the physical sciences to which the real world is compared. This procedure of science (now no more unique to science than the two previous cited in this paper) help to orient the student who somehow has acquired the notion that all in science is descriptive and real.

Another of the procedures and characteristics of science highlighted in the semester dealing with the laboratory physical sciences is the revisionary aspect of scientific theories. Again, almost any area of science may be used to illustrate the thesis. Indeed, if this characteristic is considered important enough for the promotion of tolerance and open-mindedness towards ideas, the entire fabric of physical science may be used. For the change from Ptolemaic to Copernican doctrines, from caloric to molecular ideas, from phlogiston to oxygen and combustion, and many others can be cited. In our course, the thesis is introduced and used when the concept of chemical element is approached. The ideas of the ancients—earth, fire, water, and air—and those of some alchemists—mercury, salt, and sulfur—are arrayed against the concept of Boyle and the chemical element idea of today, complete with isotopes.

We have tried to show that the subject matter of natural science can be directed towards learning the procedures and characteristics of natural science. The customary principles and facts presented in any course of science can be used to show what natural science is and how scientists operate. It is most likely that such is the case for thermodynamics, quantitative analysis, organic qualitative analysis, or radiation chemistry. It has been attempted by the author in general education physical science, where the course is both introductory and terminal, and where student awareness of what science is all about is as important as learning some basic principles.

HIGH SCHOOL BIOLOGY AND ITS RELATION TO ZOOLOGY I AT LOUISIANA STATE UNIVERSITY *

HENRY JAMES WERNER
Louisiana State University, Baton Rouge 3, Louisiana

SEVERAL events prompt me to write this article; namely, having been appointed chairman of a sub-committee to study grade distributions for the College of Arts and Sciences, lecturing in an introductory zoology class last term in which 35 per cent of the students did unsatisfactory work (D or F grade), and a remark made by a lady, very active in P.T.A. circles, "The consensus is that L.S.U. is trying to keep its enrollment down by failing 25 per cent of the freshman students."

Let me, first of all, list a few facts and then discuss them.

1. A grade distribution survey of all departments in the College of Arts and Sciences, based on the last five years, showed that with the exception of introductory mathematics more students fail to do adequate work (D or F grade) in introductory zoology than in any other course in the college.
2. Since 1952 the percentage of unsatisfactory work (D or F grade) in Zoology I has risen from 25 per cent to an alarming 42.5 per cent
3. A one year survey indicates that 30.2 per cent of the students enrolled in Zoology I have not been exposed to high school biology—69.8 per cent having taken such a course.
4. Forty-one and eight-tenths per cent of the students who did not take high school biology failed to do adequate work and 31.6 per cent of the students with a background in biology also failed to do adequate work.
5. Twenty-five and four tenths per cent of the students with no biology background earned A or B grades and 27.1 per cent of the students with biology training earned A or B grades.
6. A five year survey revealed the fact that 67 per cent of the F grades were given to students who had taken biology and 33 per cent of the F grades were given to students who had not had biology. Item 6, in lieu of the fact that it lends itself to misinterpretation, merits immediate clarification. The figures in statement 6 are proportionately in accord with the figures in statement 3. Notice that approximately twice as many students coming to us have had high school biology.
7. Using the analysis of variance technique with 226 degrees of freedom, one arrives at a T value of 0.771. This indicates that there is no significant difference between the mean grades of the two groups of students. A prior exposure to the subject matter does not help the student perform adequately in introductory zoology.

Several questions present themselves.

1. Why the increase in the percentage of unsatisfactory grades as indicated in the second statement?
2. Why is the achievement of those students having had high school biology not significantly better than that of students not having been exposed to the subject matter?
3. Are we striving for the same goals in our respective courses?
4. Is the high school biology program keeping pace with the advances and trends in the field?
5. How can the situation be rectified?

It is a perfectly acceptable procedure to list data and ask questions. It is equally important to offer suggestions which might help to alleviate the situation. I have proceeded on the assumption, a valid one, I hope, that the mental potential of both groups is approximately the same.

Remember, please, all subsequent remarks are not to be construed as an indictment. My sole aim in presenting this material is in hopes of getting answers to the problems. For the welfare of our students we had all better pause for a moment and reexamine the processes, aims, and content of our programs. Such introspection, if it comes up with creative, usable ideas is most broadening.

Contrary to the opinions of (limited, I hope) certain P.T.A. members, L.S.U. is not purposefully flunking 25 per cent of its freshman student body. In fact, any conspicuously large attrition rate disturbs the

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* Mr. Albert L. Clary, registrar of L.S.U., supplied the statistics. Without this material the paper could not have been written. Dr. B. R. Farthing, agricultural statistician, added to the accuracy of the paper by determining the T value, thus enabling me to arrive at a firm conclusion.

serious administrator and teacher. Such a statement concerning L.S.U. is ludicrous. All thoughtful individuals—regardless of their affiliations—will agree. First of all, no self-respecting faculty would permit an administration to impose such measures. Secondly, from a pure cost standpoint any large attrition rate hurts L.S.U. The operation of a university is big business, and its product, the student, is not an expendable item. Last of all, to those of us who feel an acute sense of responsibility to the student, giving unsatisfactory grades is a painful duty. One really never becomes so callous or immune that he can promiscuously dispense unsatisfactory grades.

I cannot speak for the high school biology program, but relative to Zoology I, I am in a position to tell you what we are striving for. To make crystal clear our objectives, I may tend to oversimplify the situation. We are concerned with the acquisition of technical skills and scientific facts, and the development of a scholarly attitude. Students with any aptitude quickly acquire skills and facts; however, the development of insight and appreciation of the problems in science is much more difficult. These do not represent a dichtomy in aims; rather different aspects of the fundamental problem—the understanding of biology.

I wonder quite seriously whether the high school biology program has kept abreast with the advances and trends in the field, whether the mechanics of teaching are the same as those of our academic grandfathers, and whether the qualifications of all our high school biologists are adequate. One has the right—the responsibility—to ask such questions. This is a reciprocal situation. We, in turn, are constantly on the carpet, so to speak. Parents, administrators, and high school teachers are always asking us such questions as: Have you made the course more difficult? Have you raised the standards? Is the quality of your teaching changing?

As a faculty we have not intentionally made the course more difficult, our teaching standards continue to be high but not higher, the quality of our teaching is under constant supervision from graduate laboratory assistants up to the various lecturers. But Zoology I has become increasingly more difficult and complex because of advances brought about by continual research in the field and that more stress is being given to, for instance, the interrelationship between zoology and its sister science physiology, and the allied science, chemistry. Texts currently used make those of five years ago obsolete. Contrary to belief in some circles, zoology is not a static science. The applications to fundamental principles is in a state of constant flux.

Whenever I appear in the Zoology I program, I look forward with much anticipation to the first meeting with the new freshman students. Here I am going to meet our new majors, candidates for the allied fields of medicine, dentistry, geology, and a host of others. Like my colleagues, I want to put "my best foot forward." All of us try to the best of our ability to "put across" the aims of the course. We want the student to understand and have a sense of appreciation of zoology. How disillusioned I become when 35 per cent of my class fails to obtain a satisfactory grade at the end of the term!

The big questions are: What is wrong? What can be done about it? First of all, the fault is not entirely with the students. I deny vigorously that the recent crop of entering students is "generally stupid"—unresponsive, perhaps, but definitely not stupid. By and large, the students are overwhelmed with the difference in teaching techniques, the nature of the material, and the amount of material. The average student has no appreciation for the interrelationship of zoology and the allied sciences, zoology and history, or zoology and basic concepts of life, per se. Nothing seems to have a transfer value. It is most discouraging to learn that the average student with high school biology credit has not accumulated facts nor skills from which he can

derive ideas. This we can rectify if the student shows willingness and aptitude. The greatest task—an unexpected one—is instilling a sense of pride in personal accomplishment and motivation for the subject matter per se. The work output of most students seems to be directly proportional to the proximity of exam periods. Poor study habits (or none at all) plus striving for a grade rather than insight into the subject matter could well be some of the reasons for inadequate performance. This lack of intrinsic motivation—an unfortunate attitude—is also reflected in the fact that the average student is poorly prepared for unifying concepts in zoology. In many instances unless the material is directly applicable to his contemplated future, his interests wane quickly. It is obvious to most of us in the program that the basic principles are of little or no interest to the student. At best, it is not easy for us to discuss the nature of energy, matter, metabolism, and cellular respiration. How difficult it must be for the student who lacks the proper background, who lacks proper motivation, and who lacks proper study habits!

I have two recommendations to make which, if put into effect, would go a long way toward rectifying the situation. First, a committee of biologists should be formed. This committee should consist of a representative number of high school, college, and university biologists. This group should meet at least yearly to discuss their aims, current trends, advancements, and in general to compare notes on the progress of any suggestions made and put into effect. I offer the second suggestion with some trepidation; however, I am firmly convinced that it is in order. The issue is clear cut and must be faced honestly. There needs to be a new curriculum for university students who are preparing themselves for a high school biology teaching career. It is not enough that these students have only the basic courses in biology and the allied sciences. There should and must be a distinct major in zoology and botany.

GROUP CLASSIFICATIONS OF TEACHERS WITH EVALUATIVE ATTITUDES FAVORABLE TO SCIENCE STUDY

CARL J. KLEYENSTEUBER
University of Wisconsin-Milwaukee, Milwaukee, Wisconsin

In the effort to improve the preparation of American students in the field of science many factors are operative. Perhaps increasing the course and credit requirements is not the sole or best answer. If the assumption is valid that classroom teachers can arouse interest in, and "sell" students on the importance of, certain subject matter areas, then the personalities of teachers become important in plans to encourage the study of science. If the further assumption is valid that any teacher, either with or without extensive preparation in the field of science, might encourage interest and study in the area, the interests and attitudes of various classifications of teachers becomes more important. Perhaps students placed with these teachers will gain an interest in science either directly or by absorption. There are possibilities that teacher interest may prove an effective supplement to increased credit requirements in improving achievement in science. Thus it becomes important to examine the personalities of various classifications of teachers, particularly their interests and evaluative attitudes, to discover how they compare with theoretical criteria set up for science teachers and with actual observation of practicing science teachers.

Just prior to the successful launching of the first satellite, the Allport, Vernon, and Lindzey, *Study of Values* [1] was administered to 126 male teachers selected randomly from the high schools of Wisconsin. Table I reveals the mean scores and standard deviations for various classifications of teachers and relative to their theoretical, economic, aesthetic, social, political, and religious interests and evaluative attitudes.

TABLE I

MEANS AND STANDARD DEVIATIONS OF SCORES ON THE *Study of Values* FOR CLASSIFICATIONS OF MALE TEACHERS

Classifications of Teachers		T	E	A	S	P	R
Science (36)	M	47.472	42.583	29.361	36.000	41.250	43.333
	SD	±6.739	±7.041	±5.770	±5.533	±5.085	±8.462
So. Wisconsin (64)	M	44.266	42.938	32.203	36.109	41.875	42.641
	SD	±7.833	±8.280	±7.629	±5.501	±5.311	±7.803
Small-School (63)	M	43.476	41.571	33.111	36.683	41.365	43.841
	SD	±7.268	±7.778	±8.124	±5.315	±5.251	±7.800
Large-School (63)	M	42.730	41.841	32.587	35.952	41.270	45.651
	SD	±7.503	±8.030	±7.908	±6.012	±6.255	±6.922
Age 35 Yrs. or Less (61)	M	42.815	41.508	32.015	36.569	41.554	45.615
	SD	±8.090	±7.685	±7.180	±5.438	±5.500	±7.155
Over 35 Yrs. Old (65)	M	43.410	41.918	33.738	36.049	41.066	43.820
	SD	±6.562	±8.131	±8.742	±5.927	±6.043	±7.602
Experience 5 Yrs. or Less (63)	M	42.698	40.651	32.968	37.127	41.111	45.476
	SD	±7.936	±8.189	±7.803	±5.786	±5.910	±7.325
Over 5 Yrs. Experience (63)	M	43.508	42.762	32.730	35.508	41.524	44.016
	SD	±6.789	±7.466	±8.313	±5.465	±5.628	±7.461
Social Studies (39)	M	39.205	40.077	32.564	38.410	42.897	46.846
	SD	±6.458	±7.869	±7.139	±5.665	±5.719	±7.537
State College Prepared (63)	M	43.921	43.111	31.762	36.397	40.762	44.048
	SD	±7.025	±7.783	±7.459	±5.622	±6.263	±7.480

The *Study of Values* is a forced-choice measuring instrument which indicates the relative prominence of the six evaluative attitudes. The average mean score for each category, as established by standardization, is 40. Since the measuring instrument is based on Edward Spranger's *Types of Men* [2], the definition of the theoretical man becomes particularly important in relation to science. The "theoretical man" is interested in the discovery of truth, he likes to observe and reason, and he is empirical, critical, and rational, attitudes usually associated with science. Further he is diametrically opposed to the "aesthetic man" and lacks some of the humanitarian attitude of the "social man." The scores in Table I indicate that all the groups of male teachers under consideration have attitudinal patterns which are relatively high in the theoretical value and relatively low in the aesthetic and social values. Since these scores correlate fairly closely with Spranger's criteria, it would appear that students assigned to male teachers in any of the groups under discussion might be associated with teacher personalities which are favorable to the study of science.

While all of the groups under discussion have similar patterns of relatively high and low evaluative attitudes, a difference of degree of highness and lowness is indicated by the scores in Table I. If the mean scores for the group of science teachers are used as acceptable for the prominence of attitudes for science teachers, they indicate that the evaluative attitudes of teachers from schools in Southern Wisconsin most nearly approximate those of science teachers as a whole. This situation exists possibly because of the concentration of industry and research in the southern part of the state. The mean scores are less conclusive with regard to comparison of other groups since the theoretical value is quite similar for all. However, somewhat lower aesthetic and social mean scores might indicate that teachers from larger schools rather than from small schools more nearly approximate science teachers in attitudes. Further, somewhat lower scores in the social and religious values might indicate that teachers with more than five years of experience rather than those with less experience are more similar in attitudes to science teachers. This situation also exists, possibly, because most of the large schools and most of the experienced teachers are found in the industrial areas of the state. Students in the industrial areas, then, seem to be more likely to have teachers whose attitudes would encourage the study of science.

SUMMARY AND CONCLUSIONS

The mean scores on the *Study of Values* administered in 1956 to 126 male teachers selected randomly from the schools of Wisconsin indicate that male teachers as a whole have a pattern of attitudes which approximate those defined by Spranger as being conducive to the study of science.

Groups of male teachers from schools of Southern Wisconsin most nearly approximate the evaluative attitudes of science teachers of Wisconsin. Groups of (a) male teachers from large schools and (b) male teachers with more than five years of experience approximate the evaluative attitudes of science teachers but in a lesser degree. These groups are all found in the highly industrialized area of the state.

It is felt that when students are placed with teachers who have attitudes and interests similar to those of science teachers, more interest and encouragement will be aroused in them in the study of science. Such aroused interest will supplement increased requirements as a means for improving science preparation in the schools.

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CULTURAL SCIENCE IN AMERICA

Catharine Bergen
Jersey City State College, Jersey City 5, New Jersey

Science has always been important. There have doubtless been many eras in which it was a distinct part of culture. But we need go back only about a hundred years to find a time when a man could be a highly educated and very well informed individual and at the same time almost completely neglect science. This seems to have been true in the United States in the 1850's. It was much less true in the 1870's.

In the latter decade the *Popular Science Monthly* had its beginning and included a series of articles designed to educate the beginner in biology. In that decade also *Harper's Magazine* included an adequate supply of desirable science articles dealing with the physical as well as the biological sciences;—better than the three nature articles to which the science in their issues of 1860 was limited or the news report style of science contributions in their issues of 1850. In the 1870's people were taking full cognizance of Darwin's *The Origin of Species* which had been such a shock to both scientist and layman when it was published in 1859, and by then they had already had time to digest Thomas Henry Huxley's, *Man's Place in Nature* which from 1863 on was available as an attempt to clarify Darwin's work in a more or less popular fashion, but nevertheless a fashion in which the reader could follow step by step the scientist in his thinking and his conclusions. In short there was no dearth of articles in the 1870's to acquaint the intelligent reader with the various important scientific discoveries, as well as the processes of reasoning followed by scientists. The relationship, or lack of it, between science and religion was by no means neglected; and in the *Popular Science Monthly* Herbert Spencer even considered the application of scientific methods to the social studies.

This does not mean that science for the scientists had any unusual spurt at this time. Modern science dates from about the age of Galileo in the 17th Century and has had a more or less steadily increasing development ever since. The American Association for the Advancement of Science was established in 1848 and even that had a geological organization as its predecessor. A scientific periodical for scientists, the *American Journal of Science and Arts,* was already 30 years old when the American Association was founded. Actually scientists in this country precede the 19th Century as in the case of Benjamin Franklin who can no doubt be classed as a scientist among his other accomplishments. Actually, too, there were American laymen before the 19th Century who were decidedly interested in science as is the case with Thomas Jefferson.

But although science either for the scientist or the layman was not new in this country a hundred years ago, something had, nevertheless, happened prior to 1870 to make science and scientific thinking such an integral part of general culture in America that it could no longer be ignored in any intelligent handling of that culture. Lyman Bryson has suggested that the publication of Thomas Henry Huxley's popular treatment of evolution, *Man's Place in Nature,* was the important factor because of his clarification of the meaning of and the scientific method of arriving at a theory which by the nature of its subject could not help but attract widespread attention. I should prefer to assign more credit to Darwin, however, since it was *The Origin of Species* which inspired Huxley to write his book; and yet I hesitate to place too much credit there, either. It is no secret that a man by the name of Wallace was ready to publish something similar even before Darwin had expected to announce his findings; and despite Wallace's own admission that his

work was many times more superficial than Darwin's; it is clear that the cultural milieu was in a properly prepared state for the principles of evolution to be discovered if not by one individual then by another. There are similar cases of this in several different branches of science. It may be dangerous to attribute the acculturation of science to any single or small number of events and safer to consider it as part of that highly complex matrix known as the stage of development of the culture or the spirit of the times, if you will.

To read a sampling of science articles published over a period of a hundred years is a delightful experience and a surprising one to the person who has not done it before. The reading surprises one sometimes because it is so quaint and different from that published today and sometimes because it is so much alike. Anyone at all interested in keeping up with his reading is aware of the utter impossibility of doing any kind of justice to the enormous number of books and magazines on the market today, but is greatly surprised to find this same line of thought used by the *Harper* editors as their reason for starting the magazine which they did in June 1850, and this in the days when the *Saturday Evening Post* was still a four page newspaper and a very quaint one indeed. When first issued, *Harper's Magazine* consisted of reprints from books and other periodicals as was also true of more than one magazine of that time, such as the *North American Review*. In the front of the first volume of *Harper's*, the editors have written concerning the magazine:

> "It was projected and commenced in the belief, that it might be made the means of bringing within the reach of the great mass of the American people, an immense amount of useful and entertaining reading matter, to which on account of the great number and expense of the books and periodicals in which it originally appears, they have hitherto had no access."

One is also surprised by the up-to-dateness of the opening lines of an article by Nathaniel S. Shaler of Harvard entitled, "The Influence of the Sun upon the Formation of the Earth's Surface," which appeared in the January 1900 number of the *International Monthly:*

> "The modern development of natural science has led to so great an accumulation of knowledge that it is ever becoming more and more necessary to divide the store into two distinct parts: the one containing the knowledge which may be reckoned as strictly professional in its nature, the other that of more general significance and, because of that generality, having value and interest to intelligent people who are without special knowledge of the matter."

It was about 1900 incidentally that *Harper's* which had long since ceased using reprints found it necessary to have their science articles written by those trained in science rather than professional writers.

The surprise coming from a difference between the old and the present can be seen in the first of a series of three articles by William Baxter, Jr. on "What Makes The Trolley Car Go," which can be found in the January 1900 issue of the *Popular Science Monthly*. The author somewhere says:

> "Of all the wonderful operations accomplished by the aid of electricity at the present time, none so completely mystifies the beholder as the action of the trolley car. . . . When a trolley car is seen coming down the street at a high rate of speed the effect upon the mind is very different. (*compared with the effect of contemplating electric lights*) Here we see a vast amount of weight propelled at a high velocity and yet the only source through which the power to accomplish this result is supplied is a small wire."

Suddenly coming upon passages such as this made the present author feel particularly well rewarded for all the many hours devoted to the reading of old periodicals.

It must have been difficult for the American reader in 1850 to have found a science article intended for the layman. Actually in *Harper's* for that year about 10 per cent of the titles are concerned with science, but this was the first year of publication of this magazine and many of its titles referred to short announcements rather than articles. *Harper* articles then somewhat resembled the present *Time* and *Newsweek* style. The

same may be said for the four page *Saturday Evening Post* then issued, although it is possible to find occasional short articles on scientific topics such as the manufacture of coffee or tea, or agricultural items of primary interest to farmers. A magazine called *The Living Age* was similar. It contained about 400 short articles for 1850, one in seven or eight being on scientific subjects. *The Scientific American* was started in the 1840's, but for some time had a much less intellectual approach than it does today. What we are accustomed to think of as magazine articles were available in the 1850 *North American Review* although these were all reprints from books, pamphlets, or reports. Out of 40 titles during 1850 exactly two dealt with science. One contained biographical information about the American botanist, Bartram, and the other was on meterology. The *North American Review* always included a bibliography of books received by them. It is true that hardly any science books could be found in the list. The article on meteorology had been compiled from two meteorology books by separate authors which appeared at about the same time. Both were regular textbooks, presumably for college students. The article compiled from them, however, was for laymen.

In 1860 *Harper's* was using the same type of article as at present. The only three science articles of that year include a descriptive article on elephants, one on fish which included something about the breathing of oxygen, and a discussion of insects which are prone to attack the cotton plant.

During the year 1870 *Harper's* printed 11 science articles including one each on sunspots, the electric light, the spectroscope, the thundershower, and the physics of photography, as well as those about animals or plants which were fairly common in these early magazines. The latter articles are not very different in type from the three mentioned for 1860. In the 1875 issues of *Harper's* there were in all 12 science articles including a series on "The Stone Age in Europe," by Charles Rau. Most articles in these early issues of *Harper's* did not carry the name of any author. They were probably the work of editors of the magazine. In 1872 *Popular Science Monthly,* which in 1916 became *The Scientific Monthly,* had its beginning. Its articles were not too different from those of *The Scientific Monthly* of recent years. All were more or less on scientific topics broadly interpreted so as to include philosophy and religion and some social sciences. These articles may or may not have been intended for laymen but at least they were general in nature and not research reports for specialists. The word, *Popular,* in the first name of the periodical would seem to indicate the reading audience expected. During part of the 1870's there was a series of articles in this publication which bore the title of "Biology for Young Beginners." They were written by Sarah Hackett Stevenson and were worded as in a beginning text on the subject. This magazine also started out by including reprints from books or other sources. From the very first the *Popular Science Monthly* used high standards in selecting the articles. *Harper's* did have many that were equally good but of course many fewer than *Popular Science Monthly.* In the very first issue Herbert Spencer starts a series from his book on sociology. This may strike the reader as being off the subject of science but actually Spencer starts with an elegant discussion of the scientific theories of sunspots and how scientists have arrived at them by scientific methods. He attempts to show the need of similar scientific methods in the social studies. In fact Spencer much deplores the fact that scientists will sometimes handle social problems completely unaware of the need for technical knowledge in the latter. Spencer's article presupposes no background of knowledge on the part of the reader but does require a certain level of intelligence and some concentration. It is not easy reading.

Two additional instances of the author's efforts to aid the reader in gaining a good understanding of science are typical. In

October 1875 William Crookes has an article on "The Mechanical Action of Light" in the *Popular Science Monthly.* Although the material is technical in nature, the reader may be a novice. The manner in which Crookes handles it is evident from his opening paragraph:

> "Some experiments illustrating the mechanical action of light which I have recently exhibited before the Fellows of the Royal Society, having attracted considerable attention, I propose to give here a description of some of the instruments which my researches have enabled me to construct. But to render the subject more intelligible, it will be necessary to give a brief outline of the researches which I have been carrying on for the last three or four years so that the reader may see the gradual steps which have led up to the full proof that radiation is a motive power."

It is this type of writing repeated many times over in the latter half of the 19th Century and the early 20th Century that has established science and most especially scientific method as an integral part of general culture.

In the series of three articles on "What Makes The Trolley Car Go" referred to early in this article we have an example of a different type in which the reader is nevertheless carried up to the subject from very elementary beginnings. The main part of the article opens with a discussion of simple magnetism. The author then proceeds to explain an electromagnet showing by illustrations the various steps in making one. From here he very slowly introduces the reader to those principles of electricity needed for a comprehension of the operation of the electric motor.

The *Popular Science Monthly* for 1900 has given its readers yet another valuable means of orienting themselves to science in a satisfying manner. An article under the title of "Oxygen and the Nature of Acids" was actually made up of reprints of articles by Priestley and Lavoisier which must have been published originally somewhere near the time of the American Revolution.

Both in *Harper's* and *Popular Science Monthly* there are great differences among the articles as to technical information involved. From 1870 on neither magazine seems reluctant to print articles which contain a good deal of technical material. The early technical articles, however, tend to include all necessary explanatory material except for a few words. The present author noted that *spectroscopy* and *spectrum* were seldom defined, but commonly used. It would seem that perhaps the term *spectroscopy* might have been better known to those readers than it would be today. The explanations given with the technical articles were likely to be of the type frequently found in elementary textbooks on the subject. It was as though the editors were attempting to educate the public in the sciences. There were a number of articles including some in the early 1900's which were resumés of the state of knowledge in the various branches of science. It is noteworthy that the authors of the articles seemed in no way to talk down to their readers. They assumed that their readers would be intelligent and sufficiently interested to spend some time studying the articles. As time went on, however, authors have come to make a further assumption. Many now assume that their readers will have some knowledge of science so that their articles need not go back to the very elements of the subject. This attitude on the part of authors took place much earlier in the *Popular Science Monthly* than it did in *Harper's.* In a study of *Harper's* for the years exactly divisible by five, I found no such assumption of reader background until 1950. Then examining the more recent issues, I found this in 1951 and 1952 as well, but not in 1953 and 1954. In the five year period from January 1950 to December 1954, *Harper's Magazine* published a total of 85 articles that might be considered as science articles. In nine of these it seemed to me that some science background was obligatory to understand the article. In two of the others it seemed highly desirable. The greatest backgrounds needed were probably for the series of articles by Fred Hoyle on the nature of the universe and an article on protein molecules assuming a knowledge of organic chemistry.

A similar article in a 1910 issue of *Harper's* had included the structural formulas of organic compounds but had preceded this by a rather full explanation of the symbolism involved.

In *Popular Science Monthly* there were articles back in 1875 apparently expecting an informed reader. Most of these assumed chemistry as the reader's background. I thought six of these articles called for an elementary background in the appropriate science and an additional one made it desirable. In the 1950 *Scientific Monthly* I thought 11 articles pre-supposed a knowledge background and three others made it desirable.

Very little mathematics has been used in any article intended for laymen. A few equations appeared in an article about the electrical nature of nerve actions in a 1900 issue of *The International Monthly,* but these were relegated to a footnote, albeit a long footnote. In the January 1875 issue of *Popular Science Monthly* there appeared an article entitled, "Mathematical Investigations in Physics," which was positively shocking in that it contained no mathematics. Since it was part of an address made before the American Association and therefore keyed to an audience of scientists, it is not surprising to note that the understanding reader must be familiar with optics and electricity. It is true that the author talks about mathematical discoveries in physics, but to do so without any use of mathematical symbolism is indeed a lost art.

It must not be thought from all these statements that modern authors feel less kindly toward their ignorant readers. They are being forced to proceed as they do by the greatly increased complexity and pace of science. In the 1950 *Scientific Monthly,* for example, an article with such an innocent sounding title as "Pharmacology Today" turns out to require some familiarity with the meanings of chain length and side for science its integral part in our culture, chains of organic molecules, radioactive isotopes, ionization, free radical formation, and mentions the term, Chi-square. Ionic equations are used and empirical and structural chemical formulas. Many organic chemicals are mentioned by name although this is less serious than the above. In the case of an article on "Ion Exchange" in the same magazine and for the same year, the author has taken pity on the reader to the extent of suggesting a recent book suitable for building up a background on the subject.

It is true that the *Scientific Monthly* has for many years been connected with the American Association for the Advancement of Science and hence it can be argued that its articles are not actually designed for the layman. They seem, however, to be aimed at the scientist in a field where he is not a specialist, if not to the complete layman. A scientist reading in a field other than his own is likely to be gaining a type of cultural knowledge.

The *Scientific American* is at present a magazine of this same sort. Here the scientist learns what his colleagues in other fields are doing. Many non-scientists read this periodical as well. The articles are extremely ably written, although rather highly edited, I think. The former *Scientific American* which started in 1845 was somewhat like today's *Popular Mechanics,*—cultural if you will, but catering more to news items and gadgetry than the magazines principally referred to in this article.

One may ask what of the future of cultural science. Certainly its increasing complexity will act as a deterrent to the process of its acculturation; but the increase in the pervasity of its effects will counteract this to some extent. One would not be wise to hazard too definite a prediction. The increase in science instruction in the elementary school and the plentiful supply of science books for both adult and child laymen are movements that may help the lay reader to gain at least a part of the subject matter background now frequently demanded of him. One thing is sure; we dare not lose nor would we wish to, if we dared.

PHILOSOPHY OF A PROFESSIONAL AMATEUR

B. CLIFFORD HENDRICKS *
457–24th Avenue, Longview, Washington

HIS name was Charles Franklin Kettering. It may be a coincidence that his second name was Franklin but there is reason to believe the two men, Franklin and Kettering, bore other resemblances than in that name. Inventors, both, and both skilled in a crisp style of home-spun philosophy. Willis Whitney put it, "If a fellow goes to school long he gets frozen in his thinking. Ket has always been free." [1] Samples of that un-frozen thinking may be provocative as well as interesting fare for teachers of the inventors and scientists of tomorrow.

EXCERPTS FOR EDUCATORS

Kettering taught less than three years. Yet many of his remarks are pertinent to and often arresting for teachers; even after lifted from context.

"Youngsters should be encouraged to quest and question. The trouble is we don't get interested in the commonplace things. And it is the commonplace things that make the universe."

"I learned more from that old (Mifflin, Ohio) wagon-maker than I did in college . . . the world was so wonderful (to him) and he knew so little about it that he hated to sleep."

"There's a great difference between knowing a thing and understanding it. . . . You can know a lot and not understand anything."

"The destruction of a theory is of no consequence for theories are only stepping stones. . . . In my opinion, an ounce of experimentation is worth a pound of theory."

"(My experience has taught me) to bow humbly before facts, even if they do not seem to agree with my favorite theories."

"I have no objections to the standardization of bolts and nuts and screws but I do have a terrible obsession against standardizing of ideas."

"You cant start to do a new thing and hit it right the first time. Whenever a fellow is learning a new language he still speaks with the accent of the old."

"Action without intelligence is a form of insanity, but intelligence without action is the greatest form of studipity in the world."

"All human development, no matter what form it takes, must be outside the rules; otherwise we would never have anything new."

"That which needs correction in educating (young people to become inventors) is: It is not a disgrace to fail! And that (every failure) must be analyzed for its cause. . . . They must learn how to fail intelligently. Failing is one of the greatest arts in the world."

"Every great improvement has come after repeated failures. Virtually nothing comes out right the first time. Failures, repeated failures, are the finger posts on the road to achievement."

"I think we must have the facts and understanding before a 'formula' education means anything."

"Let's put a department of future in our universities and colleges. . . . We can do something about unmade history. . . . But, we must look (more) where we are going and (less) where we have been."

His advice to a graduating class: "You are going to be servant of somebody or something. . . . To be a good servant implies. . . . Willingness to work and . . . to learn because no one of us knows very much."

WORDS ARE NOT WORKS

"If we have two words, two names for a thing we think we understand it."

"When you don't understand it you say it is 'scientific' but when you do understand it it is no longer 'scientific.'"

"We call the reaction (in the piston chamber) 'combustion' because it nicely conceals our lack of knowledge of what takes place. (It is like a doctor's) incurable disease; it's one the doctor does not know how to cure."

"There is no reason why we cannot convert sunshine without growing plants. We looked at the birds until we learned to fly but there are no feathers on the airplanes."

TALK THAT "TAKES"

"I believe you can simplify anything you understand."

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* Professor Emeritus, University of Nebraska, Lincoln, Nebraska.

[1] All quotations used are by permission of the publishers, E. P. Dutton and Company. They are from "Professional Amateur, The Biography of Charles Franklin Kettering," by T. A. Boyd. Copyright, 1957, by T. A. Boyd.

In his words: "A thermometer is a molecular speedometer."

"The second law of thermodynamics means: you cannot push something that is going faster than you are."

"If in doubt (as you fly) throw out a monkey wrench. If it goes up you are up-side-down."

MARKET MENTALITY

He evidently had faith that others than those in school could be educated. The job, however, had its headaches.

"The thing that is really hard to do is to sell the idea of progress. So many people are against it."

"If we left businessmen to raise children in the same way they try (to make a business grow) a child at nine months would have to be earning his own living.". . .

"Many discoveries have been lost because the discoverers were not tough enough to stick to their guns and make the world believe and accept."

"Nobody is smart enough to go into the business he ends up in."

"Remember that you and I get no place in the world except in proportion as we serve the fellow who pays for our dinner."

ROAD BLOCKS TO RESEARCH

"In doing a new thing . . . at least ninety per cent of the time is taken up in overcoming all sorts of new and unexpected difficulties."

"(Yet, even though) the price of progress is trouble, I do not think the price is too high."

"The Wright Brothers flew right through the smoke screen of impossibility."

When asked to reduce the time needed to finish a research assignment by adding more man-power he replied, "(Research) is like a job of hatching eggs. . . . Two hens on (one) nest of setting eggs (will not) hatch them in less than three weeks."

"Development work is always a slightly organized chaos."

"We find, in research, that a certain amount of intelligent ignorance is essential to progress. For if you know too much you wont try the thing."

"Research is a state of mind . . . a friendly welcoming attitude toward change. It is the problem-solving mind as contrasted with the let-well-enough-alone mind. . . . It is the tomorrow-mind instead of the yesterday-mind."

"The world is not yet finished. There will always be a frontier where there is an open mind and willing hands."

"We think we are conquering nature. (If so, we usually do it) on our knees and by doing exactly what nature wants done under the circumstances."

PERSONS IN THE PROGRAM

Most of his projects were cooperative in the course of their workout. Yet he did not lose sight of the individual as a participant.

Report of Lindbergh's trans-atlantic flight prompted Mrs. Kettering to exclaim, "How wonderful that he did it all alone!" "It would have been still more wonderful", was Kettering's reply, "if he had done it with a committee."

"I have always told my gang . . . I want the job to get the fellow, not the fellow get the job."

His idea of individual prestige is hinted in the quip, "At times (in our gang) one guy was ranker than the other."

HUMBLE YET HOPEFUL

"I object to people running down the future. I am going to live all the rest of my life there and I would like it to be a nice place."

"Why don't critics talk about 'trial and success method'? That is what it really is."

"We have only begun to knock a few chips from the great quarry of knowledge that has been given us to dig out and use."

"I thought (as a boy) the only thing involved in opportunity was whether I knew how to think with my head and how to do with my hands. . . . I did not know you had to have money."

THE PAY-OFF

"We talk about science triumphing over nature. We picture ourselves as . . . a knight with his sword held high and with his foot on the dragon's head, representing the laws of nature. . . . I do not like that picture at all. I would sooner picture (us) as humble workers . . . thankful . . . for an opportunity to work . . . and thankful (for) an opportunity . . . to do something for (our) fellowmen. And I can not help but think as (we) are being thankful (we may) hear a little echo from the Great Intelligence saying, 'Just in proportion as you recognize your ignorance, the road for greater knowledge will be opened to you.' "

AIR POLLUTION: AN EDUCATIONAL PROBLEM *

ALBERT B. CARR, JR.

College of Education, University of Hawaii, Honolulu, Hawaii

THE phrase air pollution means different things to different people. To a resident of Los Angeles, California, it means smog with its characteristic effects on visibility and eye irritation. To other people it means something else. It may mean smoke billowing from an industrial stack or from an apartment house incinerator. To some people it may mean a loved one lost in one of the air pollution disasters such as have occurred in London, England; Donora, Pennsylvania; the Meuse River Valley, Belgium; and Poza Rica, Mexico. To others it may mean such things as unpleasant odors, excessive laundry bills, soot and dust on the family car or the furniture, lower crop yields or damage to vegetation, and possible health hazards.

Whatever form it takes, air pollution is a community problem which in various ways concerns each of us. Like the weather, it is a popular topic of conversation. But, unlike the weather, it is something about which a great deal can be done at the present time.

Air pollution is largely the result of the complex culture in which we are living today. This culture based on power, industry, and technology is perhaps a better one to live in than past cultures. But it should be realized that along with advances in science and technology often come either new problems or an accentuation of problems that have been with us for a long time. The problem of air pollution has been with us for a long time and it has been accentuated not only by advances in science and technology but also by the needs and activities of our ever increasing population. Our population needs heating equipment, transportation, industrial activities, and domestic and municipal incinerators to dispose of its wastes. All of these are potential sources of air pollution.

Webster's Collegiate Dictionary defines the verb "pollute" as to make or render "unclean." Air pollution then becomes the act of making the air unclean. If air pollution is defined in this way, before it can be discussed, what constitutes clean or pure air must be explained. This is not an easy thing to do, because clean air varies from place to place and has also varied from time to time in the history of the earth.

A chemical analysis of pure air might reveal that it contained approximately 21 per cent oxygen, 78 per cent nitrogen, almost 1 per cent argon, less than 0.1 per cent carbon dioxide, smaller amounts of neon, xenon, krypton, and helium and water vapor varying from 0 to 3 per cent. A physical examination would reveal that it contained no solid particulate matter and that it was completely transparent. From a biological viewpoint it would be free of all biological organisms such as pollens, rusts, spores, bacteria, and viruses. From the chemical, physical and biological points of view, it is evident that pure or clean air is for all practical purposes an impossibility. It is evident also that even without man's activities there would be contamination or pollution of the atmosphere, for natural contaminants have been present in the atmosphere since before man's advent on this planet.

Air has been thought of and referred to as an "inexhaustible and immutable" resource. Today we realize that air is not an immutable resource and perhaps sometime in the future we may be forced into realizing that it is not quite as inexhaustable as we would like to think.

At one time in our country, resources such as water, forests, soil, and wildlife

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were thought of as being inexhaustible. It has been our sad experience to find out that they are not. Wasteful and harmful practices have greatly depleted and altered these once plentiful resources.

Since the turn of the century, a great deal of attention has been given to the conservation of our natural resources. From a rather slow beginning in the early part of the twentieth century, the conservation movement has expanded until today it occupies a prominent position in our American culture. Conservation education is a byword in many of our schools. This is as it should be; for it will be through education that the people of our country will become more aware of the problems confronting us and will become better equipped to deal with them.

Air pollution affects all of us. It may either have a direct effect on our health or well-being, or may affect us indirectly. Air pollution control is expensive and this is reflected in our cost of living.

Many facets of the air pollution problem are though of as being within the scope of what we refer to as "science." However, in our schools, teaching and learning activities are, for the most part, enclosed in neat little compartments. Few opportunities are provided for seeing relationships between the subject matter of science and human activities and problems.

Since air pollution is in many situations a serious community problem, our schools, as the primary agency in the community engaged in the process of education, ought to contribute in some way to the solution of the problem. By working along with other agencies in the community, the school can help young people and adults gain a better understanding of, and become better able to cope with the variety of problems associated with air pollution.

The major contaminants which go to make up the air pollution problem of a particular community vary widely from place to place. But in general all contaminants may be classified as either gaseous or aerosol (solid or liquid particulate matter).

The gases considered as contaminants are those which are not a part of the normal atmosphere, and a gas is defined as an aeriform fluid, having neither independent shape nor volume, but tending to expand indefinitely. In any consideration of the gaseous contaminants of the atmosphere, those which usually receive attention are sulfur and certain of its compounds (sulfur dioxide, sulfur trioxide, and hydrogen sulfide), nitrogen compounds (oxides of nitrogen, and ammonia), halogen compounds (hydrogen fluoride, hydrogen chloride, and organic chlorides), and certain other gases (carbon dioxide and monoxide, formaldehyde, hydrocarbons, and ozone). In particular situations certain metallic vapors and oxides also receive a great deal of attention.

The particulate contaminants of the atmosphere may be either solid or liquid and are commonly referred to as aerosols. Five major types of aerosols may be distinguished: smoke, dusts, fumes, mists, and natural aerosols.

In order to determine what contaminants are present in the atmosphere, appropriate sampling procedures, which remove the contaminants from the atmosphere for analysis, must be carried on.

The general methods used in removing gases from the atmosphere, either as part of a control program or for determination and measurement, are absorption, adsorption, condensation, and mechanical retention. In the removal of aerosols, sedimentation, impingement, filtration, centrifugation, and precipitation are the methods commonly used.

In the fight against air pollution two aspects of atmospheric contamination control must be considered. They are source control and abatement of formed contaminants. The two control fields are mutually complementary and normally overlap in their activities. However, before the installation of expensive equipment for the abatement of contaminants, the possibility

of eliminating the contaminants either before or during production must be looked at very carefully. An example of this would be in the use of coal and petroleum as industrial fuels. If sufficient sulfur could be removed from the fuel before its use, the abatement practice of scrubbing the stack gases for sulfur dioxide removal would not have to be applied.

The ideal place for installing source control methods is in the development stage of a project or in the design phase of a plant. This, however, is not always possible. Modifications of existing plants and processes with an eye to source control of atmospheric contaminants then becomes necessary.

When it is found that atmospheric pollution cannot be adequately reduced by source control methods then the solution to the particular problem must be looked for among the great variety of abatement techniques available. In general, these abatement techniques control air pollution through either retention or dispersion.

Retention involves the removal of a substantial portion of the contaminants (solid, liquid, and/or gas) from the air or gas stream and preventing their discharge into the atmosphere. The problems involved in this method are many, but engineering know-how in the field is at such a point that almost any problem can be immediately solved—if the cost can be afforded. It is unfortunate that in many cases little if any measurable monetary return is gained by the installation of abatement equipment.

Dispersion involves the reduction of the concentration of the contaminants (solid, liquid, and/or gas) to a sufficiently low level by dilution or mixing in the atmosphere.

The effects of air pollution vary widely from situation to situation. In considering the effects of air pollution on human beings it should be realized that contaminants may effect the individual either physically or psychologically. The psychosomatic effects of living in what is or what one considers to be a contaminated atmosphere may be quite detrimental. These effects are not the kind which can be accurately measured. But we can be sure that such things as smoke, disagreeable or nauseating odors, dust and dirt, and other unpleasant contaminants in the atmosphere do not contribute to the general well being of the population.

The nuisance effects of air pollution on human beings are fairly well known. Such things as reduced visibility, eye irritation, nose and throat irritation, malodors, and the like do produce psychological and sometimes physical effects in man. The effects produced by these nuisances would include lowered morale and undue concern over health.

A great many people are convinced that air pollution is a serious health hazard. However, outside of one instance, "no clear causal relation has been demonstrated between a specific chemical air pollutant and chronic disease." [1] This one instance was in the case of beryllium. It was established, on the basis of studies in a New England city and a mid-western city, that prolonged exposure to very low levels of beryllium compounds in the atmosphere around beryllium plants produced fatal cases of berylliosis (a lung disease which is readily differentiated from other diseases) in people who had never worked in the plants. However, there is a general lack of information about the effects of prolonged exposure to low concentrations of air pollutants.

In general, the effects of atmospheric contaminants depend on the nature of the contaminants, the length of the period of exposure, and the concentration of the contaminants. Up to now, nobody has been able to set up definite time-concentration limits regarding the low levels of contaminants present in the atmosphere which have met with uniform approval and acceptance.

[1] Irving R. Tabershaw, "Chemically Active Air Pollutants, "*Air Pollution: Proceedings of the United States Technical Conference on Air Pollution,* Louis C. McCabe, Chairman (New York: McGraw-Hill Book Company, Inc., 1952), pp. 469–470.

Most of the effects of air pollution on animals (livestock) are attributed to air pollution through a somewhat indirect route. The harmful effects usually arise from the intake of forage which has been contaminated by airborne toxic substances. The three contaminants "responsible for most livestock damage are arsenic, fluorine, and lead." [2] They may originate from dusting and spraying operations as well as from various industrial processes.

The principal contaminants which will cause damage to vegetation are (1) sulfur dioxide; (2) halogen gases; (3) smog gases; (4) organic compounds, such as aldehydes, ketones, and acids; (5) herbicidal sprays; and (6) ethylene, hydrogen cyanide, and mercury vapor, in enclosures like greenhouses.[3] Susceptibility to each of these classes of contaminants varies in different species of plants. Some of them are more susceptible to injury than others.

A great variety of substances are affected by exposure to the atmosphere and the contaminants it contains. Metals and alloys, stone, masonry and other building materials, textile materials, and rubber may all be adversely affected by air pollution.

One of the devices often made use of in the fight against air pollution is the enactment and enforcement of laws.

Air pollution legislation may be divided into two general classes: "(1) punitive ordinances which impose fines for violations, and (2) regulatory ordinances which seek to abate air pollution by preventing the discharge of contaminants." [4] The punishment aspect is still present in air pollution laws; however, to it has been added the concept of attacking the problem at its source.

The enactment and the enforcement of legislation designed to control air pollution is a very important aid in the fight to overcome this problem. However, legislation and its enforcement is not the whole answer to the problem. Air pollution inspectors can not be everywhere at the same time and would-be violators of the laws can almost always find ways and means of circumvention. A sound program of education must be carried on, so that people in all walks of life will become aware of their responsibilities and obligations in regard to the air pollution problem. Only then will the kind of cooperative program be forthcoming which will be able to solve the air pollution problem.

[2] P. H. Phillips, "The Effects of Air Pollutants on Farm Animals," *Air Pollution Handbook,* Paul Magill and others, editors (New York: McGraw-Hill Book Company, Inc. 1956), p. 8–3.

[3] Moyer Thomas and Russel Hendricks, "The Effect of Air Pollution on Plants," *Air Pollution Handbook,* Paul Magill and others, editors (New York: McGraw-Hill Book Company, Inc., 1956), p. 9–3.

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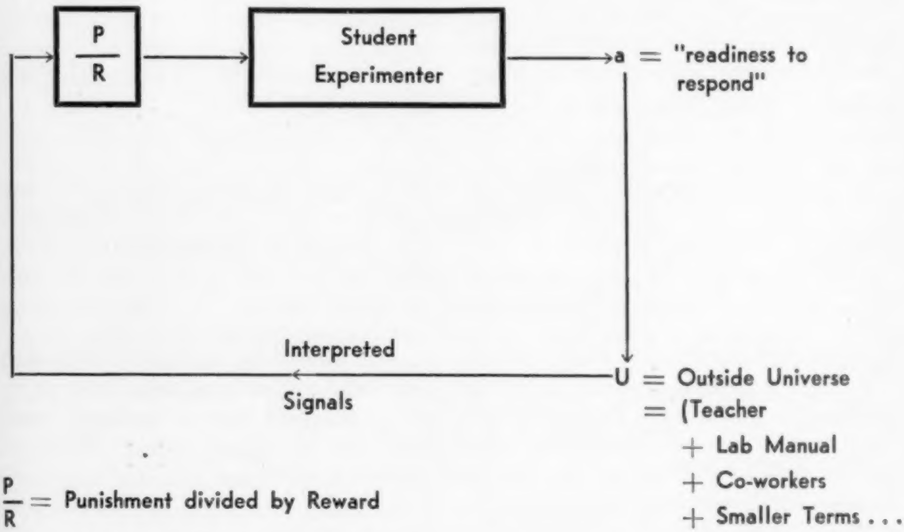
[4] *Smoke and Air Pollution—New York and New Jersey,* (New York: Interstate Sanitation Commission, 1958), p. 90.

LEARNING FEEDBACK AND EXPERIMENTAL TENSION

BOWMAN C. COLLINS
Lick-Wilmerding High School, San Francisco, California

BEHAVIORAL scientists and others have pointed out the similarities between an electronic feedback system (single or multiple loop) and the "life circuits" of a general organism. In a single loop feedback system, there exists a signal path opposite to the main direction of transmission, joined to the latter at both ends. A typical simple "life circuit" is found in a very interesting book edited by Roy R. Grinker, M.D.[1]

If we relabel and add another circuit element, we have:



$\frac{P}{R}$ = Punishment divided by Reward

Negative feedback maintains P/R relatively constant. Also, feedback ("You are/are not doing this right") is distributed in time—it extends over the whole period. The student gets an explanation from the teacher; he asks a question and gets an immediate answer. He begins a procedure; he then rereads the explicit instructions of the Lab Manual for confirmation. He observes the procedures used by, and asks a question of, one of the other 20 students doing identical "experiments"; he receives an answer.

How would our diagram change if we replaced the "student" by an "actual experimenter?" As we know, actual experimentation involves tedium, elation, frustration, anxiety, hope and "X"; also, time. The "Cape Canaveral Type Activity"[2] is an attempt to answer a related question, "Can students be given work in the lab which has a correlation closer (than Explicit Laboratory Manual Exercises) to *actual* experimental problems?"

We showed students some precision blocks of wood, about 2″ x 3″ x 8″. By attaching some weights (machined small volumes of brass and aluminum) to the

[1] Roy R. Grinker, Ed., *Toward a Unified Theory of Human Behavior,* Basic Books, Inc., 1956, New York p. 267. (Chapter Nineteen, pp. 264–277, presentation by Jules Henry.)

[2] Paper presented by the author at the Northern California Section of the American Association of Physics Teachers, May 14, 1960 at City College of San Francisco.

bottom of one block, the instructor showed the class the "water line"—about one-half inch down from the top surface of the block (3″ x 8″). We said, "Without weighing your anchor weights, but computing their volumes and doing *more* computing, and without wetting your block, calculate how much weight the teacher would have to place on *top* of your block-plus-under-weights in order for your 'submarine' to barely be awash." The block (plus attachments) of the first group sank in our main tank before about half of the calculated weights could be placed on top by the "firing officer," the instructor. A dud! Visible to all, the trouble was caused by a "trivial" slide rule error. A second group, unable to wait, achieved illegal success ("46.3 grams on top will make our block barely awash") in their lab table sink. They had checked their work carefully, but not their enthusiasm. Most of the groups, *but not all,* were successful; "finishing early" was not a status symbol.

Reinforcement here—both negative and positive—was unique, vivid, and had long-lasting effect. More important, learning feedback was *delayed,* an essential ingredient (not to say inevitable) in *real* experimentation-and-calculation. Does the dictionary say that "to experiment" means to "verify the known in a manner specified by the lab manual and the teacher?" Does "experiment" mean that students should avoid all experimental tension, confident that what worked last semester will now work again for 20 students, all doing the same "experiment?" Would we, as teachers, solve a puzzle in *Scientific American* by continually asking, "Am I on the right track?"

These are complex questions and simple answers cannot be given!

A STUDENT'S VIEW OF SUMMER HIGH SCHOOL CHEMISTRY

MARY LYNN BURGIS
Isidore Newman School, New Orleans, Louisiana

MANY high schools have taught laboratory science courses in the summer so that students who failed or did poorly could repeat them. A newer development is the summer class for the average or superior student. Some courses leading to advanced placement for the gifted are now taught during the summer, but there is also an increasing number of summer classes for those who, like myself, want to take a time-consuming laboratory course when it would not interfere with other work.

Last summer I experienced one of the most grueling, but nonetheless one of the most rewarding, activities of my life. For eight weeks in the hot, lazy New Orleans summer, I took a course which had not been offered by my school in the summer before.

Since none of my friends had taken such a course, I had little advance information, but I was sure that it would be much easier than the regular course. When the course began, I saw that the laboratory with temperatures in the nineties everyday and other factors would complicate the matter. Standing over a Bunsen burner in an ankle length plastic laboratory apron without air conditioning didn't make the work very pleasant.

Another problem stemmed from the fact that while I had to spend five or six hours on homework every night, my friends were all sitting around doing absolutely nothing. I found this extremely disturbing and once or twice I almost yielded to the temptation of joining them. It seems much easier to

study during the regular school year when everyone else is doing it, too.

In the regular academic year, material is introduced in small amounts. Students have time to think about what they have learned and to make this part of their total knowledge. Digestion and integration of new material are harder in the intensive course.

It is true, however, that only one course is studied at a time, and a student does not forget by the end of the course what was covered the first week. There is a big advantage in the smaller class, where the teacher can consider individual needs and interests of the students. Field trips are much easier to arrange; our group of four students could hear everything our American Sugar Company guide said at the refinery, for example, and we could ask all the questions we liked.

Qualitative and quantitative analysis, and organic chemistry are usually treated lightly in high school chemistry classes because of lack of time. Our more flexible summer schedule permitted us to work in the laboratory uninterrupted for as long as four hours, something not common among nine month courses.

As a junior I have already completed the chemistry course usually taken in this grade, and I have more time for other subjects. Students can take extra courses by attending summer schools; some high schools are even considering summer classes for all students.

There is merit in such proposals, and for many students summer science classes can be helpful. Care must be taken to insure that students and teachers realize there are psychological and physical factors to be considered. The content might be the same, but methods cannot always be used interchangeably in intensive and regular courses.

Looking back on my own experience, I'm only happy and thankful that it's all over, but I'm very glad that I took the summer chemistry course. There was no shortage of apparatus or space as there sometimes is during the regular year. Individual attention was given to each student. My friends, who wasted the summer, are now taking the course I have completed.

Teachers and administrators should, in my opinion, offer laboratory science courses in the summer, but both the educators and the students should study the problems and differences in advance. Careful counseling is necessary. When the right students are in the right kind of a course, the summer laboratory work can be interesting in spite of the heat and thoughts of friends killing time or having fun. There will undoubtedly be a bigger demand for summer science courses in the future.

RADIATION HAZARDS AND WHAT IS BEING DONE ABOUT THEM *

EDITH H. QUIMBY

College of Physicians and Surgeons, Columbia University, New York, New York

THE *dangers* of exposure to radiation are continually being presented via all types of mass communication. The *benefits* to humanity from the use of x-rays and radioactive isotopes are largely ignored in such discussions. It is true that *in sufficient quantity* radiation can bring about all the bad things attributed to it. *In sufficient quantity* must be kept in mind. Alcohol, in sufficient quantity, will deprive a person of all reason and decency. But not everyone that takes a cocktail or a glass of wine becomes a drunken sot,—and not everyone

* Abstract of address delivered at the Women's Luncheon, New York Meeting of the American Association for the Advancement of Science, December 30, 1960.

who has a series of x-ray examinations, or works in a radioisotope laboratory, or even experiences radioactive fall-out, is going to develop radiation damage, either in herself or her descendants.

A certain amount of radiation is unavoidable—cosmic rays, radioactive materials in the earth, and even in our own bodies, keep us continually exposed, at a very low level. The problem is to establish a level above this natural one which constitutes a reasonable calculated risk, where the probable benefits to humanity outweigh the possible damage, and then set up means for assuring that this level is not exceeded. This sort of risk philosophy is at the basis of most human behavior. For instance, in the United States the automobile, in the hands of the general populace, is a lethal weapon, killing and maiming thousands of innocent victims each year. Yet nobody but a crank would think of suggesting that all automobiles be eliminated. We accept the fact that the advantages of motor transportation far outweight the disadvantages, but we do try to set up traffic rules to control the hazards.

And nobody but a crank would think of suggesting that all x-ray machines and nuclear energy plants should be eliminated. The tremendous medical value of the radiations, both in diagnosis and treatment, their ever-widening use in all branches of scientific research, their important practical applications in industry make it apparent that their use will increase rather than diminish. The balance toward the widespread advantage is great indeed. The disadvantages are much less tangible.

The bad results which have been produced by large doses of radiation improperly used are well known, and at present have practically ceased to occur. They are readily avoided by proper "traffic rules." The present concern is with possible harm from small doses such as are received from diagnostic x-rays, from laboratory use of radioactive materials, from world-wide fallout from nuclear weapons. Now it must be remembered that any of the damages produced by radiation, such as cataract formation, leukemia, genetic changes, may arise without any exposure to radiation other than the unescapable natural sources. In order to find out whether small doses of radiation increase the frequency of these, extended statistical study involving millions of people would be necessary. Since this is almost impossible, extrapolation must be made from the effects of higher doses, and it is never certain that such extrapolations are warranted. But it is certain that drawing conclusions from the observation of a few sporadic cases is not warranted.

Dose-effect data will be presented to show that under presently adopted safety rules, no individual should ever receive enough radiation to produce a *somatic* damage,—that is, a damage to the irradiated person. For all such effects it appears necessary for a lower limit of dose to be exceeded before anything happens, and this can almost always be prevented. *Genetic* damage presents a different picture. Here the irradiated individual shows no change, but her offspring may be defective. Obviously genetic damage can occur only to people who are going to have children, and can result only from radiation reaching the reproductive organs, before the children are born. There is much misunderstanding about this, resulting in the ludicrous (but true) episodes of 60-year-old grandmothers objecting to dental x-rays because they "read in the newspaper," or "someone told them" it would be bad for their grandchildren.

Obviously data on human genetic damage is exceedingly difficult to obtain. It must be remembered that 2 per cent of all children born in the United States during recent generations show genetic defects—not from any exposure of the parents to radiation; they haven't had it,—but from genetic changes that have occurred in their ancestry from other causes. The question then is to set a "calculated risk" level which will be reasonable, balanced against the ad-

vantages to the population of uses of radiation. On a basis of the best present information it is estimated that if *every potential parent* received a dose during each reproductive year of his or her life, equal to 5 times the natural background, the immediate increase in the defective population would be about 1,000 per year, with an ultimate rise after some hundreds of years to ten times this. These, in the annual baby crop of three million, would be impossible to find statistically. This does not mean that the matter be brushed aside without further consideration. Any increase in the defective population puts an extra burden on society, financial, moral, and sentimental. But this must be balanced against the also partly intangible advantages of diagnostic and therapeutic radiation to many thousands of people, as well as the research and industrial advances.

It should be pointed out that racial genetic damage depends on *the average* exposure to all potential parents. It does not matter to posterity if one person receives more and another less; no one individual is very important genetically to the human race. According to wide-spread studies of radiation to populations, including all medical radiology and fall-out from nuclear weapons, the average population dose in the United States at the present time and in the foreseeable future is only about two-thirds of that mentioned above. It therefore appears that the balance is weighted toward the advantage side.

Because the importance of the "fall-out" contribution has been magnified disproportionately by the publicity given it in various discussions, a special analysis will be made of its possibilities. The difficulty of obtaining adequate statistical human data for such low doses is almost insuperable, and the emotional factor has been so strongly injected into this particular phase of the problem, that no categorical answer is possible. It can, however, be stated that on the worst assumptions the contribution of fall-out to human death or serious disease could not exceed a few hundred a year. These could never be found statistically in the population. It is therefore not possible to say that these additional deaths cannot have been caused by fallout; it is only possible to say it has not been proved that they *can*.

Members of the medical and dental professions realize their responsibility for maintaining the average population dose at a low level. At the same time it is obvious that no patient should be made to fore-go the advantages of really desirable x-ray examinations. Within this framework, of doing all the studies that are really worthwhile, and sharply restricting other uses of radiation, it has been practicable to set up "traffic rules" that should maintain radiation hazards at a very low level compared to radiation benefits.

AN EVALUATION OF THE INTRODUCTORY CHEMISTRY COURSE ON FILM

KENNETH E. ANDERSON
Dean, School of Education, The University of Kansas, Lawrence, Kansas

FRED S. MONTGOMERY
Director, Bureau of Visual Instruction, The University of Kansas, Lawrence, Kansas

AND

SID F. MOORE
Principal, Wichita High School East, Wichita, Kansas

INTRODUCTION

DURING the 1957–58 school year, the Encyclopaedia Britannica Films, Inc., produced on film a series of 160 lectures and demonstrations conducted by Professor John F. Baxter of the University of Florida. The Bureau of Visual Instruction of the University of Kansas purchased a set of these films in color for use by Kansas high schools.

Prior to the beginning of the school year 1959–60, the five large high schools of Wichita, Kansas, indicated a willingness to participate in the evaluation of the introductory chemistry course on film. The local coordinator of the project and a co-investigator in the study was Sid F. Moore, Principal of the Wichita High School East.

A total of thirty-three chemistry classes in the five high schools participated and a total of 590 students completed all the testing involved in the study. Nine teachers taught the thirty-three classes. Although three teachers taught both film and non-film classes, the mean number of semester hours of preparation in college science was 68 for the non-film teachers and 51 for the film teachers. The mean number of hours of preparation in college chemistry was 35 for the non-film teachers and 25 for the film teachers. The non-film teachers had on the average, 20 years of teaching experience as contrasted to seven years of teaching experience for the film teachers. Thus, as these factors influence achievement in chemistry, the balance was in favor of the non-film classes.

The thirty-three classes were composed of seven film classes and 26 non-film classes. In the case of the 26 non-film classes, the number was reduced to eight by combining the classes of each teacher. No statistical violence was done since an inspection of the means and variances for the criterion measures used in the study appeared to be relatively homogeneous. Thus the final composition of the groups used in the comparison were eight non-film groups and seven film groups.

THE PROBLEM

The problem was one of testing which method produced superior results in measured achievement during the one school year of instruction: the conventional method or the film method of instruction. The design adopted required that differences which might occur in performance of the contrasting groups were to be tested for significance by assumption of the null hypothesis. The several specific null hypotheses tested are stated in the section entitled *Statistical Analyses of the Data.*

TESTS USED IN THE STUDY

In order to secure necessary data for a statistical test of the null hypothesis, it was decided to administer four tests as follows:

1. The *Anderson Chemistry Test,* Form Am,[1] as a pre-test, mid-year test, and post-test at the end of the school year.
2. The *Laboratory Techniques and Apparatus Test for High School Chemistry*[2] as a post-test at the end of the school year.
3. The *A.C.S.-N.S.T.A. Cooperative Examination—High School Chemistry Form 1959* as a pre-test and post-test.[3] Part I was used as a pre-test and Part II was used as a post-test.
4. The SCAT or *School and College Ability Tests.*[4] Total score on this test was used in the caluculations.

Raw scores obtained from these tests were used in the statistical analyses which follow. All pre-tests were administered during the first two weeks of the school year and all post-tests were administered within the last two weeks of the school year. The SCAT and mid-year chemistry tests were administered at the mid-point of the school year.

STATISTICAL ANALYSES OF THE DATA

One of the assumptions underlying the use of many statistical techniques, and the techniques used in this study such as the t test and analysis of variance and covariance, is reasonable normality of test data. The scores obtained for the four tests used in this study were tabulated into frequency distributions and plotted on normal probability paper. All four lines were approximately straight indicating normality of test data for all four tests.

[1] Published by the World Book Company, Yonkers-on-Hudson, New York.

[2] Published by Kenneth E. Anderson, Dean, School of Education, The University of Kansas, 1960.

[3] Published by the Examination Committee—A.C.S., St. Louis University.

[4] Published by the Cooperative Test Division, Educational Testing Service, Princeton, New Jersey.

Analyses I

Did the Film Groups Achieve Significantly More than the Non-Film Groups on the Anderson Chemistry Test with SCAT and Pre-Test Scores Held Constant?

Before the test data in each treatment group could be pooled, the assumptions basic to pooling had to be satisfied, namely: (1) homogeneity of variances, and (2) homogeneity of means.

The assumptions were satisfied for six film groups and these were called *Film Group A.* One film group could not be pooled with the others and was called *Film Group B.*

Five non-film groups satisfied the assumptions as did the three other non-film groups. These were called *Non-Film Group A* and *Non-Film Group B.*

1. Film Group A (N=112) versus Non-Film Group A (N=280).

The two groups were compared by using the analysis of covariance technique holding pre-test and SCAT scores constant. The assumptions of homogeneity of variances and regression were met and the final results appear in Table I.

On the basis of the results in Table I, one can conclude that the non-film group achieved significantly more than the film group on the final test with pre-test and SCAT scores held constant.

2. Film Group A (N = 112) versus non-Film Group B (N = 182).

TABLE I

ANALYSIS OF COVARIANCE

Source of Variation	d.f.	SS	MS	F
Within	388	20,138.34	51.90	
Between	1	13,615.50	13,615.50	26.53
Total	389	33,753.84	....	P<.01

Adjusted Means: Film Group = 45.47
Non-Film Group = 57.79

The technique of analysis of covariance could not be used as the two groups were not homogeneous with respect to variances on the post-test. This was also true regarding variances on the pre-test and the SCAT. Thus the groups had to be compared on each variable by computing an observed t in the usual way and by computing a criterion t using the Cochran-Cox method.[5] If the observed t is greater than the criterion t at the specified level, the difference in means is considered to be significant. Table II gives the results of the computation for this comparison.

[5] Palmer O. Johnson, *Statistical Methods in Research.* Prentice-Hall, Inc., New York, 1949, pp. 74–75.

On the basis of the results in Table II, one can conclude that no difference in final achievement existed between the groups.

3. Film Group B (N=16) versus Non-Film Group A (N=280).

The two groups were homogeneous with respect to variances and regression and Table III shows the results of the final step in analysis of covariance.

Thus one can conclude that no difference in final achievement existed between the groups holding pre-test and SCAT scores constant.

4. Film Group B (N=16) versus Non-Film Group B (N=182).

The two groups were homogeneous with respect to variances and regression and the

TABLE II

OBSERVED AND CRITERION t's

Test	Observed t	Criterion t		Means
Post	0.00	1.98	(5%)	Film Group = 44.52 Non-Film Group = 44.52 Difference was not significant.
SCAT	1.24	1.97	(5%)	Film Group = 80.88 Non-Film Group = 79.64 Difference was not significant.
Pre	0.80	1.98	(5%)	Film Group = 25.63 Non-Film Group = 24.83 Difference was not significant.

TABLE III

ANALYSIS OF COVARIANCE

Source of Variation	d.f.	SS	MS	F
Within	292	17,069.18	58.46	....
Between	1	77.41	77.41	1.32
Total	293	17,146.59	....	P>.05

Adjusted Means: Film Group = 55.91
Non-Film Group = 58.16

TABLE IV

ANALYSIS OF COVARIANCE

Source of Variation	d.f.	SS	MS	F
Within	194	18,891.64	97.38	
Between	1	1,464.86	1,464.86	15.04
Total	195	20,356.50	....	P<.01

Adjusted means: Film Group = 54.67
Non-Film Group = 44.64

TABLE V

ANALYSIS OF COVARIANCE

Source of Variation	d.f.	SS	MS	F
Within	342	19,469.87	56.93	....
Between	1	1,305.31	1,305.31	22.93
Total	343	20,775.18	....	P<.01

Adjusted means: Film Group = 20.16
Non-Film Group = 15.77

final step in analysis of covariance appears in Table IV.

Thus on the basis of the results in Table IV, one can conclude that the film group achieved significantly more than the non-film group on the final examination with pre-test and SCAT scores held constant.

Analyses II

Did the Film Groups Achieve Significantly More than the Non-Film Groups on the A.C.S.-N.S.T.A. Chemistry Examination with SCAT and Pre-Test Scores Held Constant?

Before the test data in each treatment group could be pooled, homogeneity of means and variances had to exist. Six film groups met these assumptions and one did not. These were called Film Group A and Film Group B.

Five non-film groups met the assumptions, but three non-film groups did not and had to remain as separate groups. Thus, these were called Non-Film Groups A, B, C, and D.

1. Film Group A (N=109) versus Non-Film Group A (N=237).

Homogeneity of variances and regression existed and the final step in the analysis of covariance process appears in Table V.

One may conclude that the film group achieved significantly more than the non-film group on the final examination with pre-test and SCAT scores held constant.

2. Film Group A (N=109) versus Non-Film Group B (N=86).

Homogeneity of regression did not exist and hence the t test was used since homogeneity of variances existed on all three measures. Table VI shows the results.

Thus one can conclude that the non-film group achieved significantly more on the final examination in spite of a slight superiority of the film group on the SCAT.

3. Film Group A (N=109) versus Non-Film Group C (N=57).

Homogeneity of variances and regression existed and the final step in the analysis of covariance technique appears in Table VII.

Thus one can conclude that no difference in achievement on the final examination existed between the groups with pre-test and SCAT scores held constant.

TABLE VI

t TESTS

Test	t Value	Means
Post	2.65*	Film Group = 19.84 Non-Film Group = 22.97
SCAT	2.52**	Film Group = 80.72 Non-Film Group = 75.43
Pre	1.15	Film Group = 2.61 Non-Film Group = 3.16

* Significant at the 1 per cent level.
** Significant at the 5 per cent level.

4. Film Group A (N=109) versus Non-Film Group D (N=82).

Non-homogeneity of variances existed between the groups on the post-test. Hence the t test or t test with the criterion-t test was used to make the comparisons. Table VIII gives the results.

One can conclude that the non-film group scored significantly higher on the final examination. This statement must be tempered by the fact that the non-film group scored significantly higher on the SCAT.

5. Film Group B (N=19) versus Non-Film Group A (N=237).

Non-homogeneity of variances existed between the groups on the final examination. Thus the t test or t test with the criterion-t test was used. Table 9 shows the results.

Thus one can conclude that no difference in achievement on the final test existed between the groups.

6. Film Group B (N=19) versus Non-Film Group B (N=86).

TABLE VII

ANALYSIS OF COVARIANCE

Source of Variation	d.f.	SS	MS	F
Within	162	9,030.06	55.74	....
Between	1	24.32	24.32	0.44
Total	163	9,054.38	....	P>.05

Adjusted means: Film Group = 21.08
Non-Film Group = 21.97

TABLE VIII

OBSERVED AND CRITERION t's

Test	Observed t	Criterion t	Means
Post	3.12	2.64 (1%)	Film Group = 19.84 Non-Film Group = 24.49 Difference was significant at the 1 per cent level.
SCAT	3.61	No criterion t needed—homogeneity of variances	Film Group = 80.72 Non-Film Group = 87.88 Difference was significant at the 1 per cent level.
Pre	0.95	1.99 (5%)	Film Group = 2.61 Non-Film Group = 4.31 Difference was not significant.

TABLE IX

OBSERVED AND CRITERION t's

Test	Observed t	Criterion t	Means
Post	0.29	1.79 (5%)	Film Group = 16.58 Non-Film Group = 15.92 Difference was not significant.
SCAT	0.65	No criterion t needed—homogeneity of variances	Film Group = 82.47 Non-Film Group = 79.86 Difference was not significant.
Pre	1.52	No criterion t needed—homogeneity of variances	Film Group = 2.05 Non-Film Group = 3.39 Difference was not significant.

Homogeneity of variances and regression existed and the final step in analysis of covariance appears in Table X.

Thus one can conclude that the non-film group achieved significantly more than the film group on the final examination with pre-test and SCAT scores held constant.

7. Film Group B (N=19) versus Non-Film Group C (N=57).

Since non-homogeneity of variances existed between the groups on the final test, the t test or t test with the criterion-t was used. Table XI shows the results.

Thus one can conclude that the non-film group achieved significantly more on the final examination. However, it scored significantly higher on the pre-test at the 5 per cent level.

8. Film Group B (N=19) versus Non-Film Group D (N=82).

Since non-homogeneity of variances existed between the groups on the final examination, the t test or t test with the criterion-t test was used. Table XII gives the results.

TABLE X

ANALYSIS OF COVARIANCE

Source of Variation	d.f.	SS	MS	F
Within	101	4,108.11	40.67	....
Between	1	1,328.05	1,328.05	32.65
Total	102	5,436.16	....	P<.01

Adjusted Means: Film Group = 15.85
Non-Film Group = 23.13

TABLE XI

OBSERVED AND CRITERION t's

Test	Observed t	Criterion t	Means
Post	2.83	2.77 (1%)	Film Group = 16.58 Non-Film Group = 24.37 Difference was significant at the 1 per cent level.
SCAT	0.84	No criterion t needed—homogeneity of variances	Film Group = 82.47 Non-Film Group = 86.40 Difference was not significant.
Pre	2.10	2.04 (5%) 2.75 (1%)	Film Group = 2.05 Non-Film Group = 5.10 Difference was significant at the 5 per cent level.

TABLE XII

OBSERVED AND CRITERION t's

Test	Observed t	Criterion t	Means
Post	2.84	2.77 (1%)	Film Group = 16.58 Non-Film Group = 24.48 Difference was significant at the 1 per cent level.
SCAT	1.70	No criterion t needed—homogeneity of variances	Film Group = 82.47 Non-Film Group = 87.88 Difference was not significant.
Pre	2.06	2.05 (5%) 2.77 (1%)	Film Group = 2.05 Non-Film Group = 4.32 Difference was significant at the 5 per cent level.

Thus one can conclude that the non-film group achieved significantly more than the film group on the final examination. However, it scored significantly higher on the pre-test at the 5 per cent level.

Analyses III

Did the Film Groups Achieve Significantly More than the Non-Film Groups on the Laboratory Techniques and Apparatus Test with SCAT Scores Held Constant?

A word of explanation is in order at this point. The test was constructed specifically for this study. The test consists of 50 multiple-choice questions with three possible responses. The test was constructed after examining about fifteen laboratory manuals now in current use in high school chemistry. Also, Lessons 62 and 63 in the Instructor's Manual and the Student's Manual for the Encyclopaedia Britannica Films were examined.

Thus, the test had validity insofar as it sampled the materials in these sources. It was recognized that the test was not an adequate substitute for an examination based on actual laboratory performance.

The *Laboratory Techniques and Apparatus Test* was administered to 3,253 Kansas high school chemistry students during the last two weeks of the 1959–60 school year. The test was scored by counting the number of correct answers, there being but one best answer among the three responses provided for each of the fifty items. The next step was to obtain the score for each student on the even-numbered items in order to provide data for the computation of a coefficient of reliability. The coefficient of reliability was computed by means of the technique described in *Topics in Statistics for Students in Education.*[6] The reliability coefficient was computed as follows:

$$\text{Reliability (Total Test)} = 1 - \frac{\text{Variance (Difference)}}{\text{Variance (Total Test)}}$$

$$\text{Reliability} = 1 - \frac{8.2372}{21.7294}$$

$$\text{Reliability} = 0.621$$

The standard error of measurement was computed as follows:

$$\text{Standard Error of Measurement} = \sqrt{\text{Variance (Difference)}}$$

$$\text{Standard Error of Measurement} = \sqrt{8.2372}$$

$$\text{Standard Error of Measurement} = 2.87$$

Thus, the test seemed to the investigators to possess fair reliability, and although the test proved to be somewhat easy, the discriminatory power of the items was good.

What about item difficulty and item discrimination? An examination of the data indicated that the 50 items in general tended to be easy for the group. The average percentage of difficulty for the fifty items was 66.30 with a range of from about 10 to about 98. As for item discrimination, a greater percentage of students in the upper half got each item right as contrasted to the percentage in the lower half. In fact, the differences in percentages were statistically significant in favor of the upper group in all instances but two. There are many ways of arriving at a statistical index of discrimination. The one used here was a test of significance of the difference in percentages between the upper and lower half using the following formula:

$$X = \frac{\frac{t_1}{n_1} - \frac{t_2}{n_2}}{\sqrt{\left(\frac{t_1 + t_2}{n_1 + n_2}\right)\left(1 - \frac{t_1 + t_2}{n_1 + n_2}\right)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

The X is then referred to the normal table. If the X exceeds a $(\pm)$ 1.96 the difference

[6] Kenneth E. Anderson and Herbert A. Smith, *Topics in Statistics for Students in Education.* The Interstate Printers and Publishers, Inc., Danville, Illinois, 1958, pp. 112–115.

TABLE XIII

OBSERVED AND CRITERION t's

Test	Observed t	Criterion t	Means
Laboratory	2.99	2.62 (1%)	Film Group = 34.48 Non-Film Group = 39.63 Difference was significant at the 1 per cent level.
SCAT	2.78	No criterion t needed—homogeneity of variances	Film Group = 80.98 Non-Film Group = 75.55 Difference was significant at the 1 per cent level.

in percentages is significant at the 5 per cent level. If the X exceeds a (±) 2.58, the difference in percentages is significant at the 1 per cent level. Actually a nomograph was used in this instance.

As for plausibility of decoys, some students picked one of the decoys other than the right or best answer for every item of the test. An examination of other items, however, showed that some decoys were not too attractive to the students.

Before the test data in each treatment group could be pooled, homogeneity of means and variances had to be established. The eight film groups met the assumptions and were pooled to form one Film Group A. The eight non-film groups failed to meet the assumptions and had to be divided into the following groups: (1) Non-Film Group A, (2) Non-Film Group B, (3) Non-Film Group C, (4) Non-Film Group D, and (5) Non-Film Group E.

1. Film Group A (N=128) versus Non-Film Group A (N=99).

Non-homogeneity of variances existed on the laboratory test and the t test or t test with the criterion-t test was used. The results appear in Table XIII.

Thus, one can conclude that the non-film group achieved significantly more than the film group on the final examination despite the superiority of the film group on the SCAT.

2. Film Group A (N=128) versus Non-Film Group B (N=112).

Homogeneity of variances and regression existed between the groups on the laboratory test and the final step in the analysis of covariance technique appears in Table XIV.

Thus one can conclude that the film group achieved significantly more than the non-film group on the laboratory test with SCAT scores held constant.

3. Film Group A (N=128) versus Non-Film Group C (N=124).

Homogeneity of variances did not exist between the groups on the laboratory test so the t test or t test with the criterion-t test was used. Table XV shows the results.

Thus one can conclude that no difference in achievement on the laboratory test existed between the groups despite the fact that the non-film group scored significantly higher on the SCAT.

TABLE XIV

ANALYSIS OF COVARIANCE

Source of Variation	d.f.	SS	MS	F
Within	237	3,989.50	16.83	
Between	1	173.10	173.10	10.29
Total	238	4,162.60		P<.01

Adjusted means: Film Group = 34.40
Non-Film Group = 32.27

4. Film Group A (N=128) versus Non-Film Group D (N=70).

Homogeneity of variances and regression existed and the final step in analysis of covariance appears in Table XVI.

One can conclude that no difference between the groups existed as to achievement on the laboratory test with SCAT scores held constant.

5. Film Group A (N=128) versus Non-Film Group E (N=57).

Homogeneity of variances did not exist between the groups on the laboratory test. Hence, the t test or t test with the criterion-t test was used. Table XVII gives the results.

Thus, one can conclude that the non-film group scored significantly higher (5 per cent level) than the film group on the laboratory test. However, the non-film group scored significantly higher (5 per cent level) than the film group on the SCAT.

Analyses IV

Six of the groups at one high school were given the *Anderson Chemistry Test* as a pre-test, mid-year test, and post-test. ***Were the gains from pre-test to mid-year test and from the mid-year test to the post-test greater for the three film groups than for the three non-film groups?***

TABLE XV

OBSERVED AND CRITERION t's

Test	Observed t	Criterion t	Means
Laboratory	1.18	1.98 (5%)	Film Group = 34.48 Non-Film Group = 35.06 Difference was not significant.
SCAT	2.98	No criterion t needed—homogeneity of variances	Film Group = 80.98 Non-Film Group = 85.86 Difference was significant at the 1 per cent level.

TABLE XVI

ANALYSIS OF COVARIANCE

Source of Variation	d.f.	SS	MS	F
Within	195	3,342.45	17.14	....
Between	1	5.64	5.64	0.33
Total	196	3,348.09	....	P>.05

Adjusted means: Film Group = 34.49
Non-Film Group = 34.14

TABLE XVII

OBSERVED AND CRITERION t's

Test	Observed t	Criterion t	Means
Laboratory	2.00	2.65 (1%) 1.99 (5%)	Film Group = 34.48 Non-Film Group = 36.12 Difference was significant at the 5 per cent level.
SCAT	2.20	2.64 (1%) 2.00 (5%)	Film Group = 80.98 Non-Film Group = 86.40 Difference was significant at the 5 per cent level.

The t test for matched groups was used and the results appear in Tables XVIII and XIX.

A comparison of both tables reveals that both the film groups and the non-film groups gained a significant amount in achievement from the pre-test to mid-year test and from the mid-year test to the post-test. However, the three non-film group gains were all significant at the 0.1 per cent level whereas two of the film groups gains from mid-year test to post-test were significant at the 1 per cent level.

If gains are used as scores and if we combine all film groups and all non-film groups for a comparison by means of the non-correlated t test, we obtain the results shown in Table XX.

Thus, the results in Tables XVIII, XIX, and XX would warrant the statement that the non-film group gained a significant amount in achievement during each half-

TABLE XVIII

GAINS FOR FILM GROUP FROM PRE-TEST TO MID-YEAR TEST AND FROM MID-YEAR TEST TO POST-TEST

Statistic	Film Group A I	A II	B I	B II	C I	C II
$\bar{D}$	18.20	6.73	25.11	6.39	23.67	4.93
t	8.63	3.35	8.02	3.38	11.43	4.32
P	P<.001	P<.01	P<.001	P<.01	P<.001	P<.001
N	15	15	18	18	15	15

I—Represents Pre-test to Mid-year test.
II—Represents Mid-year to Post-test.

TABLE XIX

GAINS FOR NON-FILM GROUPS FROM PRE-TEST TO MID-YEAR TEST AND FROM MID-YEAR TEST TO POST-TEST

Statistic	Non-Film Group A I	A II	B I	B II	C I	C II
$\bar{D}$	17.82	14.73	18.48	8.90	24.07	10.88
t	7.89	6.88	16.50	9.57	21.30	14.13
P	P<.001	P<.001	P<.001	P<.001	P<.001	P<.001
N	11	11	48	48	56	56

I—Represents Pre-test to Mid-year test.
II—Represents Mid-year to Post-test.

TABLE XX

COMPARISON OF FILM AND NON-FILM GROUPS ON GAINS FROM THE PRE-TEST TO MID-YEAR TEST AND FROM MID-YEAR TEST TO POST-TEST

Comparison	t	P	Means
I–II	0.86	P>.05	Film Group = 22.50 Non-Film Group = 21.14
II–III	3.91	P<.001	Film Group = 6.04 Non-Film Group = 10.42

I—Represents Pre-test.
II—Represents Mid-year test.
III—Represents Post-test.

Homogeneity of variance existed for each comparison. Degrees of freedom in both comparisons were 161.

year. The same cannot be said with the same degree of assurance for the film groups. One might say that the reason for the significant difference in means in favor of the non-film groups during the last half of the year was that the film groups became bored with the constant showing of the films.

Analyses V

Three teachers taught both film and non-film classes. *Did the Film Classes Achieve Significantly More than the Non-Film Classes on:*

1. *The Anderson Chemistry Test with SCAT and Pre-test Scores held Constant?*
2. *The A.C.S.-N.S.T.A. Chemistry Examination with SCAT and Pre-test Scores Held Constant?*
3. *The Laboratory Techniques and Apparatus Test with SCAT Scores Held Constant?*

Teacher X had one film class of 16 students and two non-film classes with a total of 42 students. All assumptions basic to pooling and for analysis of covariance were met unless otherwise indicated. The results of the three analyses in terms of the three criterion measures appear in Tables XXI, XXII, and XXIII.

One may summarize the results for Teacher X as follows:

1. Although the film class had higher adjusted means than the non-film classes on the *Anderson Chemistry Test* and on the *A.C.S.-N.S.T.A. Chemistry Examination* with SCAT and pre-test scores held constant, the results were not significantly different.
2. The film class achieved significantly more than the non-film classes on the *Laboratory Techniques and Apparatus Test* with SCAT scores held constant. The adjusted means were 36.90 and 34.59 respectively.

Teacher Y had two film classes with a total of 32 students and one non-film class

TABLE XXI

ANALYSIS OF COVARIANCE—ANDERSON CHEMISTRY TEST—TEACHER X

Source of Variation	d.f.	SS	MS	F
Within	54	2,891.66	53.55	....
Between	1	9.69	9.69	0.18
Total	55	2,901.30	....	P>.05

Adjusted means: Film Class = 55.00
Non-Film Classes = 54.07

TABLE XXII

ANALYSIS OF COVARIANCE—A.C.S.-N.S.T.A. CHEMISTRY EXAMINATION—TEACHER X

Source of Variation	d.f.	SS	MS	F
Within	54	2,862.19	53.00	....
Between	1	72.06	72.06	1.36
Total	55	2,934.25	....	P>.05

Adjusted means: Film Class = 21.40
Non-Film Classes = 18.89

TABLE XXIII

ANALYSIS OF COVARIANCE—LABORATORY TECHNIQUES AND APPARATUS TEST—TEACHER X

Source of Variation	d.f.	SS	MS	F
Within	55	447.64	8.14	....
Between	1	61.73	61.73	7.58
Total	56	509.37	....	P<.01

Adjusted means: Film Class = 36.90
Non-Film Classes = 34.59

with 13 students. The results of the three analyses in terms of the three criterion measures appear in Tables XXIV, XXV, and XXVI.

One may summarize the results for Teacher Y as follows:

1. The non-film classes achieved significantly more than the film class on the *Anderson Chemistry Test* with SCAT and pre-test scores held constant. The adjusted means were 56.32 and 48.24 respectively.

2. The film classes achieved significantly more than the non-film class on the *A.C.S.-N.S.T.A. Chemistry Examination* with SCAT and pre-test scores held constant. The adjusted means were 23.05 and 15.61 respectively.

3. The non-film class achieved significantly more than the film classes on the *Laboratory Techniques and Apparatus Test* with SCAT scores held constant. The adjusted means were 38.44 and 33.07 respectively.

Teacher Z had one film class of 18 students and three non-film classes with a total of 82 students. The results of the three analyses in terms of the three criterion

TABLE XXIV

ANALYSIS OF COVARIANCE—ANDERSON CHEMISTRY TEST—TEACHER Y

Source of Variation	d.f.	SS	MS	F
Within	40	1,526.91	38.17	....
Between	1	923.22	923.22	24.19
Total	42	2,450.13	....	$P<.01$

Adjusted means: Film Classes = 48.24
Non-Film Class = 56.32

TABLE XXV

ANALYSIS OF COVARIANCE—A.C.S.-N.S.T.A. CHEMISTRY EXAMINATION—TEACHER Y

Source of Variation	d.f.	SS	MS	F
Within	40	2,411.91	60.30	....
Between	1	429.02	429.02	7.11
Total	42	2,840.93	....	$P<.05$

Adjusted means: Film Classes = 23.05
Non-Film Class = 15.61

TABLE XXVI

ANALYSIS OF COVARIANCE—LABORATORY TECHNIQUES AND APPARATUS TEST—TEACHER Y

Source of Variation	d.f.	SS	MS	F
Within	42	771.12	18.36	....
Between	1	255.15	255.15	13.90
Total	43	1,026.27	....	$P<.01$

Adjusted means: Film Classes = 33.07
Non-Film Class = 38.44

TABLE XXVII

ANALYSIS OF COVARIANCE—ANDERSON CHEMISTRY TEST—TEACHER Z

Source of Variation	d.f.	SS	MS	F
Within	96	3,839.72	39.99	....
Between	1	1,816.89	1,816.89	45.43
Total	97	5,656.61	....	$P<.01$

Adjusted means: Film Class = 46.04
Non-Film Classes = 57.48

measures appear in Tables XXVII, XXVIII, and XXIX.

In the case of the *A.C.S.-N.S.T.A. Chemistry Examination,* the two groups under comparison failed to meet the assumption of homogeneity of variances. Hence, the technique of analysis of covariance could not be used. Hence, the t test or t test with the criterion-t test was used to make the comparisons. Table XXVIII shows the results.

One may summarize the results for Teacher Z as follows:

1. The non-film classes achieved significantly more than the film class on the *Anderson Chemistry Test* with SCAT and pre-test scores held constant. The adjusted means were 57.48 and 46.04 respectively.

2. Although the non-film classes achieved significantly more than the film class on the *A.C.S.-N.S.T.A. Chemistry Examination* at the 5 per cent level, the non-film classes scored significantly higher than the film class at the 5 per cent level on the SCAT. The non-film classes also scored higher than the film class on the pre-test but the

TABLE XXVIII

OBSERVED AND CRITERION t's—A.C.S.-N.S.T.A. CHEMISTRY EXAMINATION—TEACHER Z

Test	Observed t	Criterion t	Means
Post	2.48	2.11 (5%)	Film Class = 17.22 Non-Film Classes = 24.49 Difference was significant at the 5 per cent level.
SCAT	2.43	No criterion t needed—homogeneity of variances	Film Class = 79.94 Non-Film Classes = 87.88 Difference was significant at the 2 per cent level.
Pre	0.95	No criterion t needed—homogeneity of variances	Film Class = 3.22 Non-Film Classes = 4.32 Difference was not significant.

TABLE XXIX

ANALYSIS OF COVARIANCE—LABORATORY TECHNIQUES AND APPARATUS TEST—TEACHER Z

Source of Variation	d.f.	SS	MS	F
Within	97	998.09	10.29	....
Between	1	2.61	2.61	0.25
Total	98	1,000.70	....	P>.05

Adjusted means: Film Class = 35.58
Non-Film Classes = 35.15

TABLE XXX

STUDENTS' OPINION OF THE FILMS

Question	Percentage Indicating		
	HS*	AA**	U***
1. How well did the films stimulate your voluntary effort to study chemistry?	7.59	57.24	35.17
2. How well did the films give you an understanding of chemistry?	32.42	55.17	12.41
3. How well did the films stimulate your interest in science?	34.48	50.35	15.17
4. How useful were the films in terms of your vocational objective?	20.00	58.62	21.38
5. How well did the films contribute to your cultural development?	25.52	62.07	12.41

* Highly satisfactory (well pleased).
** About average (moderately satisfied).
*** Unsatisfactory (disappointed).
N = 145.

difference was not significant. The means on the criterion measure were 24.49 and 17.22 respectively.

3. Although the film class achieved more than the non-film classes on the *Laboratory Techniques and Apparatus Test* with SCAT scores held constant, the difference was not significant. The adjusted means were 35.58 and 35.15 respectively.

STUDENT OPINION

The students in the film classes were asked to respond to two sets of questions which appear in Tables XXX and XXXI.

TABLE XXXI

STUDENTS' EVALUATION OF CERTAIN ASPECTS OF THE FILM COURSE

Question	Percentage Indicating Yes	Percentage Indicating No
1. Do you feel you would have done better in the conventional chemistry course?	54.48	45.52
2. Do you feel that there were too many films?	54.48	45.52
3. Would you have liked more laboratory work?	83.45	16.55
4. Would you be willing to take another course with about the same number of films involved?	48.28	51.72
5. Do you feel you have used your textbook as much as you would have in a conventional chemistry course?	6.21	93.79
6. Have you worked as hard for the course as you might have for a conventional chemistry course?	35.17	64.83
7. Were the films too difficult?	17.24	82.76

N = 145

In summarizing student reaction to the two sets of questions, one might generalize as follows:

1. The films gave them an understanding of chemistry and stimulated interest in science.
2. The films did not stimulate voluntary effort to study chemistry.
3. The films did a fair job in terms of contributing to vocational objectives and cultural development.
4. A slight majority felt they would have done better in a conventional course, but over 80 per cent would have liked more laboratory work.
5. The students did not feel there were too many films and about 80 per cent felt that the films were not too difficult.
6. A good majority of the students felt they did not work as hard for the film course as they would have for a conventional one, but about equal numbers indicated they would be willing to take another film course.
7. All but about 6 per cent felt that the textbook was not used as much as it would have been in a conventional course.

SUMMARY AND LIMITATIONS OF THE STUDY

The data presented in this study would seem to indicate that the students in the non-film classes achieved more in high school chemistry than did the students in the film classes. This statement is supported by the fact that in eight of the seventeen direct comparisons, the differences in measured achievement were significant and in favor of the non-film group. Only three out of the seventeen differences were significant and in favor of the film groups. This was especially true for the *A.C.S.-N.S.T.A. Chemistry Examination* where five of the eight comparisons were significant and in favor of the non-film groups. The results were about equally divided in terms of the *Anderson Chemistry Test.* This may be due to the fact that the tests measured somewhat different abilities in chemistry. Two of the five comparisons for the *Laboratory Techniques and Apparatus Test* were significant and in favor of the non-film groups. Only one comparison was significant and in favor of the film groups.

When gains were compared on the *Anderson Chemistry Test* from the pre-test to the mid-year test and from the mid-year test to the post-test, there was some indication that the non-film groups were somewhat superior and that the film groups suffered a greater drop in achievement during the last half of the year than did the non-film groups. The students' reaction would seem to indicate that too many films were shown and that boredom had set in. This may account for the film groups greater drop in mean gain during the last half of the year.

When the film and non-film groups taught by the same teacher were compared, the results were in favor of the non-film

groups. Four out of the nine comparisons were significant and in favor of the non-film groups. Only two of the nine comparisons were significant and in favor of the film groups.

The students in the film classes were asked to give their reaction to several questions and in general one might say that the students felt they would have done better in a conventional chemistry course. Evidently, the students in the film group missed the usual laboratory instruction since about 83 per cent would have liked more laboratory work. The students felt they might have done better had they used a textbook designed to accompany the films rather than using the textbook employed with the non-film groups.

The students thought the film instructor was excellent and that the colored film added a great deal. They also felt that the experiments shown in the films used excellent equipment not usually available in a high school laboratory. They felt that the use of this equipment and the fine execution of the experiments was something they would have missed in the conventional laboratory approach. They also liked the wide range of industrial applications of chemistry shown in the films. They felt that this was quite broadening and stimulated their interest in science.

The students felt there were too many films but almost an equal number would be willing to take another film course.

All in all, despite the better achievement of the non-film classes on the chemistry examinations used, one cannot say that the students' reaction was negative. In fact, they felt that they had gained much by being in the film classes.

Several of the students, and apparently the better students, felt that a better procedure would be a wise selection of the films by the teacher in terms of: (1) his preparation to teach chemistry, (2) the equipment and facilities available, and (3) the ability of his students to master the level of chemistry he is able to present.

Several students suggested that more than five class hours per week be given to instruction in chemistry if all the films were to be used, so that more time could be devoted to class discussion and work in the laboratory. Others suggested that chemistry be taught in the usual way and that all of the films be shown and at a set hour after the close of the school or at a time convenient for all those enrolled in chemistry. They felt that if students attended these showings on their own, that they would greatly augment their understanding of chemistry and achieve significantly more. Thus, it would seem that the students want the films available and that much is to be gained from viewing them. However, it would seem that the films should not replace the regular mode of instruction. Thus, it seems fair to say that films, and possibly television and teaching machines too, will not replace the teacher. It may also be said that when films are used via television, nothing is added. Teaching with or without films, television, or machines, will be effective only as we employ teachers who know their subject matter and have the know-how to put the material across. However, the teacher may greatly augment his effectiveness by good aids such as films, television, and machines, if he employs these aids properly.

This study had obvious limitations. It was confined to one school system and the film and non-film groups were not selected at random. Neither were the teachers equal in college preparation and in experience. These and other limitations temper the conclusions and summary statements of this study.

It has been proposed and a study will be made using a factorial design with covariance involving such variables as: (1) film or non-film instruction, (2) sex, (3) semesters of science completed before taking chemistry, (4) semesters of mathematics completed before taking chemistry, and (5) professional goal "go to college for a science career" or "go to college for a non-

science career." An equal number of students will be selected at random to fill the cells of such a design and the pre-test and SCAT scores will be held constant. If such a study can be completed without violating basic assumptions, a significant contribution will have been made to the literature in science education.

AN EVALUATION OF THE INTRODUCTORY CHEMISTRY COURSE ON FILM BY FACTORIAL DESIGN AND COVARIANCE WITH METHOD AND SEX AS THE MAIN VARIABLES

KENNETH E. ANDERSON
Dean, School of Education, University of Kansas, Lawrence, Kansas

FRED S. MONTGOMERY
Director, Bureau of Visual Instruction, University of Kansas, Lawrence, Kansas

AND

DALE P. SCANNELL
Director, Bureau of Educational Research and Service, University of Kansas, Lawrence, Kansas

INTRODUCTION

A PREVIOUS article entitled "An Evaluation of the Introductory Chemistry Course on Film" describes the population and rationale behind the present study.

PROBLEM

The problem was one of testing which method produced superior results in measured achievement during one year of instruction: the conventional method or the film method of instruction. The design of the study was a 2 x 2 factorial type. The factors were the two sexes (male and female) and the two methods (film or non-film) of instruction. Analysis of covariance was introduced in that the pre-test and SCAT scores were held constant. The factorial design employed permitted stratification of the data and the testing of three null hypotheses as follows:

1. Students taught by the film method did not differ in achievement in high school chemistry from the students taught by the non-film method with pre-test and SCAT scores held constant.
2. Male students did not differ in achievement in high school chemistry from the female students with pre-test and SCAT scores held constant.
3. The sexes did not differ in achievement in high school chemistry when taught by the film method and when taught by the non-film method with pre-test and SCAT scores held constant.

The primary hypothesis was the first and hypotheses two and three help make the first more meaningful than had they not been introduced into the problem. From the standpoint of the efficiency of the factorial design, it can be said that we will have tested one hypothesis regarding interaction and two hypotheses concerning main effects. If the single-factor plan of experiment had been used, the two main hypotheses would have required separate treatments and no information would have been possible concerning the effect of interaction. The following four groups could have been compared at once in one analysis of covariance: (1) film-male, (2) film-female, (3) non-film-male, and (4) non-film-female. However, six t tests would have been subsequently required, and again the interaction effect would not have been available.

TESTS USED IN THE STUDY

In order to secure necessary data for a statistical test of the three null hypotheses, two tests were administered:

1. The *Anderson Chemistry Test, Form Am,*[1] as a pre-test and post-test at the beginning and end of the school year. Raw scores were used in the calculations.

2. The SCAT or *School and College Ability Tests.*[2] The SCAT was given at the mid-point of the school year. Total raw scores on the test were used in the calculations.

PROCEDURE AND STATISTICAL ANALYSIS

There were 590 students distributed as follows:

Film Method—Male	79
Film Method—Female	49
Non-Film Method—Male	289
Non-Film Method—Female	173

Ten students were selected by means of random numbers from each of the four groups and their scores appear in Table I. The post-test scores of the 590 students distributed themselves in an approximately normal fashion. This was also true of the distributions for the pre-test and SCAT scores. Thus the set of 40 scores in Table I represent random scores from these normal populations.

The next step was the calculation of the sums appearing in Table II.

TABLE II

SUMS OF SCORES, SUMS OF SCORES SQUARED, AND SUMS OF CROSS-PRODUCTS

Group	Male		Female	
Film	ΣX	= 241	ΣX	= 214
	ΣX^2	= 6,781	ΣX^2	= 4,878
	ΣY	= 737	ΣY	= 788
	ΣY^2	= 55,503	ΣY^2	= 64,894
	ΣZ	= 408	ΣZ	= 396
	ΣZ^2	= 17,034	ΣZ^2	= 16,860
	ΣXY	= 18,529	ΣXY	= 17,474
	ΣYZ	= 30,504	ΣYZ	= 32,747
	ΣXZ	= 10,185	ΣXZ	= 8,700
Non-Film	ΣX	= 297	ΣX	= 235
	ΣX^2	= 9,057	ΣX^2	= 6,141
	ΣY	= 754	ΣY	= 825
	ΣY^2	= 61,750	ΣY^2	= 68,361
	ΣZ	= 508	ΣZ	= 479
	ΣZ^2	= 27,240	ΣZ^2	= 23,381
	ΣXY	= 22,247	ΣXY	= 19,544
	ΣYZ	= 39,920	ΣYZ	= 39,565
	ΣXZ	= 15,166	ΣXZ	= 11,357

[1] Published by the World Book Company, Yonkers-on-Hudson, New York.

[2] Published by the Cooperative Test Division, Educational Testing Service, Princeton, New Jersey.

TABLE I

SCORES OF FORTY STUDENTS

Group		Male			Female		
		X*	Y**	Z***	X*	Y**	Z***
Film	1	26	80	39	21	90	52
	2	7	67	41	19	82	51
	3	25	80	40	9	36	20
	4	19	62	36	24	87	49
	5	22	85	43	22	75	32
	6	16	60	44	29	96	44
	7	29	74	39	16	86	38
	8	17	58	27	22	76	35
	9	40	92	49	25	94	50
	10	40	79	50	27	66	25
Non-Film	1	24	65	58	20	76	52
	2	27	83	60	21	80	34
	3	33	88	53	37	91	48
	4	30	72	43	11	85	55
	5	35	16	32	24	71	49
	6	38	88	74	29	82	49
	7	28	99	53	21	84	53
	8	25	69	33	16	83	41
	9	23	85	54	36	88	56
	10	34	89	48	20	85	42

* Raw scores on the pre-test.

** Raw SCAT scores.

*** Raw scores on the post-test.

The data in Table II were used to obtain the sums of squares or SS's which appear in Table III. Five sums of squares had to be computed for X, Y, Z, XY, YZ, and XZ or a total of 30 in all.

The computation of the five SS's for Z are shown below. Similar computations were done for X and Y.

1. SS or Σz^2 for the total sample of 40 cases.

$\Sigma Z = 408 + 396 + 508 + 479 = 1{,}791$

$\Sigma Z^2 = 17{,}034 + 16{,}860 + 27{,}240 + 23{,}381 = 84{,}515$

$$SS = \frac{N\Sigma Z^2 - (EZ)^2}{N} = \frac{40(84{,}515) - (1{,}791)^2}{40}$$

SS (total) = 4,322.98

2. SS or Σz^2 for method.

ΣZ (film) $= 408 + 396 = 804$

ΣZ (non-film) $= 508 + 479 = 987$

$1{,}791$

$$SS = \frac{\Sigma Z^2}{N/2} - \frac{(\Sigma Z_T)^2}{N}$$

$$SS = \frac{(804)^2 + (987)^2}{40/2} - \frac{(1{,}791)^2}{40}$$

SS (method) = 837.22

3. SS or Σz^2 for sex.

ΣZ (male) $= 408 + 508 = 916$

ΣZ (female) $= 396 + 479 = 875$

$1{,}791$

$$SS = \frac{\Sigma Z^2}{N/2} - \frac{(\Sigma Z_T)^2}{N}$$

$$S = \frac{(916)^2 + (875)^2}{40/2} - \frac{(1{,}791)^2}{40}$$

SS (sex) = 42.02

4. SS or Σz^2 for interaction.

	Male	Female
Film	408	396
Non-Film	508	479

$\Sigma Z = 408 + 396 + 508 + 479 = 1{,}791$

$$SS \text{ (cells)} = \frac{\Sigma Z^2}{N/4} - \frac{(\Sigma Z_T)^2}{N}$$

$$SS \text{ (cells)} = \frac{(408)^2 + (396)^2 + (508)^2 + (479)^2}{40/4} - \frac{(1{,}791)^2}{40}$$

SS (cells) = 886.47

SS = SS (cells) − SS (method) − SS (sex)

SS = 886.47 − 837.22 − 42.02

SS (interaction) = 7.[illegible]

5. SS or Σz^2 for within groups.

SS = SS (total) − SS (method) − SS (sex) − SS (interaction)

SS = 4,322.98 − 837.22 − 42.02 − 7.23

SS (within) = 3,436.51

The computation of the five SS's for XZ are shown below. Similar computations were done for XY and YZ.

1. SS or Σxz for the total sample of 40 cases.

$\Sigma X = 241 + 214 + 297 + 235 = 987$

$\Sigma Z = 408 + 396 + 508 + 479 = 1{,}791$

$\Sigma XZ = 10{,}185 + 8{,}700 + 15{,}166 + 11{,}357 = 45{,}408$

$$SS = \frac{N\Sigma XZ - (\Sigma X)(\Sigma Z)}{N}$$

$$SS = \frac{40(45{,}408) - (987)(1{,}791)}{40}$$

SS (total) = 1,215.08

2. SS or Σxz for method.

ΣX (film) $= 241 + 214 = 455$

ΣZ (film) $= 408 + 396 = 804$

ΣX (non-film) $= 297 + 235 = 532$

ΣZ (non-film) $= 508 + 479 = 987$

ΣX (total or film and non-film) $= 455 + 532 = 987$

ΣZ (total or film and non-film) $= 804 + 987 = 1{,}791$

$$SS = \frac{(\Sigma X)(\Sigma Z) + (\Sigma X)(\Sigma Z)}{N/2} - \frac{(\Sigma X_T)(\Sigma Z_T)}{N}$$

$$SS = \frac{(455)(804) + (532)(987)}{40/2} - \frac{(987)(1{,}791)}{40}$$

SS (method) = 352.27

3. SS or Σxz for sex.

ΣX (male) $= 241 + 297 = 538$

ΣZ (male) $= 408 + 508 = 916$

ΣX (female) $= 214 + 235 = 449$

ΣZ (female) $= 396 + 479 = 875$

ΣX (total or male and female) $= 538 + 449 = 987$

ΣZ (total or male and female) $= 916 + 875 = 1{,}791$

$$SS = \frac{(\Sigma X)(\Sigma Z) + (\Sigma X)(\Sigma Z)}{N/2} - \frac{(\Sigma X_T)(\Sigma Z_T)}{N}$$

$$SS = \frac{(538)(916) + (449)(875)}{40/2} - \frac{(987)(1{,}791)}{40}$$

SS (sex) = 91.22

4. SS or Σxz for interaction.

	Male	Female
Film	$\Sigma X = 241$	$\Sigma X = 214$
	$\Sigma Z = 408$	$\Sigma Z = 396$
Non-film	$\Sigma X = 297$	$\Sigma X = 235$
	$\Sigma Z = 508$	$\Sigma Z = 479$

ΣX (total for all four cells) = 987
ΣZ (total for all four cells) = 1,791

$$SS = \frac{(\Sigma X)(\Sigma Z)+(\Sigma X)(\Sigma Z)+(\Sigma X)(\Sigma Z)+(\Sigma X)(\Sigma Z)}{N/4} - \frac{(\Sigma X_T)(\Sigma Z_T)}{N}$$

$$SS = \frac{(241)(408)+(214)(396)+(297)(508)+(231)(497)}{40/4} - \frac{(987)(1{,}791)}{40}$$

SS (interaction) = 14.88

5. SS or Σxz for within groups.

SS = SS (total) − (method) − SS (sex) − SS (interaction)
SS = 1,215.08 − 352.87 − 91.22 − 14.88
SS (within) = 756.71

Table III has SS's for method plus within, sex plus within and interaction plus within. These are the values which must be used in order for the computations to be comparable to the within as used in simple ordinary analysis of covariance with no stratification. The coefficients b_1 and b_2 were then calculated for method, sex, and interaction using the within plus values as they appear in Table III. The coefficients for within and total were also calculated. The following formulas were used as in simple analysis of covariance:

$$b_1 = \frac{(\Sigma xz)(\Sigma y^2) - (\Sigma yz)(\Sigma xy)}{(\Sigma x^2)(\Sigma y^2) - (\Sigma xy)^2}$$

$$b_2 = \frac{(\Sigma x^2)(\Sigma yz) - (\Sigma xy)(\Sigma xz)}{(\Sigma x^2)(\Sigma y^2) - (\Sigma xy)^2}$$

The b_1 and b_2 values appear in Table IV.

The adjusted SS's were obtained using the generalized formula shown below. The illustration shows the calculation for method using the data in Tables III and IV.

TABLE IV

REGRESSION COEFFICIENTS

	b_1	b_2
Method plus Within	.237	.382
Sex plus Within	.199	.345
Interaction plus Within	.118	.378
Within	.108	.380
Total	.317	.350

$SS = \Sigma z^2 - b_1\Sigma xz - b_2\Sigma yz$
$SS = 4{,}273.73 - (.237)(1{,}108.98) - (.382)(3{,}887.95)$
SS (method plus Within) = 2,526.14

The adjusted SS's appear in Table V. A word of explanation is in order at this point. Since the SS's which appear in Table III were within plus values, the adjusted SS for within must be subtracted from the adjusted SS's for method plus within, sex plus within, and interaction plus within, to return to simple analysis of covariance. Thus, the values which appear in Table V for

TABLE III

BASIC DATA TABLE SUMS OF SQUARES

Source of Variation	Σx^2	Σxy	Σy^2	Σyz	Σz^2	Σxz
Method	148.22	103.95	72.90	247.05	837.22	352.27
Sex	198.02	−271.45	372.10	−125.05	42.02	91.22
Interaction	30.63	−17.50	10.00	−8.50	7.23	14.88
Within	2,125.91	1,387.80	9,182.60	3,640.90	3,436.51	756.71
Total	2,502.78	1,202.80	9,637.60	3,754.40	4,322.98	1,215.08
Method plus Within	2,274.13	1,491.75	9,255.50	3,887.95	4,273.73	1,108.98
Sex plus Within	2,323.93	1,116.35	9,554.70	3,515.85	3,478.53	847.93
Interaction plus Within	2,156.54	1,370.30	9,192.60	3,632.40	3,443.74	771.59

method, sex, and interaction were calculated as follows:

Method $= 2{,}526.14 - 1{,}970.64 = 555.50$
Sex $= 2{,}097.67 - 1{,}970.64 = 127.03$
Interaction $= 1{,}981.29 - 1{,}970.64 = 10.65$

Please note that in ordinary analysis of covariance the between SS plus the within SS equals the total SS. If we add the sums of squares for within, sex, interaction, and within, the total of 2,663.82 exceeds the total SS of 2,623.53. This will be explained at a later point.

The mean squares or variance estimates were obtained by dividing each SS by the proper degrees of freedom. The degrees of freedom for method, sex, and interaction were one less than the number of variables involved or one. The degrees of freedom for within were found by subtracting the three associated with method, sex, and interaction, and the two associated with the control variables from 39 or 40–1. The significance of the mean squares was determined by entering the F table with 1 and 34 degrees of freedom. The mean square for method was the only significant one and indicates that a significant difference in chemistry achievement occurred with pretest and SCAT scores held constant in favor of the film or the non-film group. Since the F value for sex was not significant, no bias was introduced by this factor. Also, since the F value for interaction was not significant, the difference in achievement of the students in the film and non-film methods cannot be accounted for on the basis of being a male or a female when taught by the film method and when taught by the non-film method.

Since the mean squares for sex and interaction were not significant, the SS's for sex and interaction were added to the SS for within to secure a new error term. The new SS's appear in Table VI.

The new SS for within appears in Table VII and the problem has now been re-

TABLE V

ADJUSTED SUMS OF SQUARES

Source of Variation	d.f.	SS	MS	Probability
Method	1	555.50	9.58	$P<.01$
Sex	1	127.03	2.19	$P>.05$
Interaction	1	10.65	0.18	$P>.05$
Within	34	1,970.64	....	....
Total	37	2,623.53	....	....

TABLE VI

SUMS OF SQUARES FOR WITHIN PLUS SEX PLUS INTERACTION

Source of Variation	Σx^2	Σxy	Σy^2	Σyz	Σz^2	Σxz
Within	2,354.56	1,098.85	9,564.70	3,507.35	3,485.76	862.81
	$b_1 = .2064$				$b_2 = .3430$	

Adjusted SS = 2,104.66

TABLE VII

ANALYSIS OF COVARIANCE

Source of Variation	d.f.	SS	MS	F
Within	36	2,104.66	58.46	....
Between or Method	1	518.87	518.87	8.86
Total	37	2,623.53	....	$P<.01$

TABLE VIII

NEW SS FOR FILM AND NON-FILM GROUPS

	N	Σx^2	Σxy	Σy^2	Σyz	Σz^2	Σxz
Film	20	1,307.75	1,309.25	4,115.75	1,946.00	1,573.20	594.00
Non-film	20	1,046.80	−210.40	5,448.95	1,561.35	1,912.55	268.80

duced to ordinary analysis of covariance. Please note that the within SS plus the between SS now equal the total SS.

Entering the F table with 1 and 36 degrees of freedom, we note that the F value of 8.86 was significant at the 1 per cent level. Before securing the adjusted means, homogeneity of variances and homogeneity of regression must be established between the film and non-film groups. This necessitated calculating new SS's for the film and non-film groups which appear in Table VIII.

Homogeneity of variances was tested for by using the unadjusted SS as follows:

$$F = \frac{1{,}912.55/19}{1{,}573.20/19} = 1.22$$

Homogeneity of regression was tested for by using the adjusted SS as follows:

$$F = \frac{1{,}360.86/19}{652.31/19} = 2.09$$

Entering the F table with 19 and 19 degrees of freedom, we note that neither F ratio was significant.

Which group achieved the most with pre-test and SCAT scores held constant? In order to answer this, the adjusted means must be available. The calculations of these appear in Table IX.

We were now in a position to draw the following conclusion on the basis of the data in Tables VII and IX: the non-film group achieved significantly more than the film group with pre-test and SCAT scores held constant. Since the F values for sex and interaction were not significant, the conclusion was not biased by the factor of sex nor influenced by an interaction between sex and method. It is planned to introduce factors other than sex into additional factorial designs. In this way, it will be possible to vary all the essential conditions simultaneously rather than one at a time, thus resulting in greater efficiency and comprehensiveness. The results, therefore, have wider applicability than do single experiments, since the ordinary analysis gives information only in respect to a narrowly restricted set of conditions.

TABLE IX

ADJUSTED MEANS

	Means			Difference from Grand Mean	
Group	Pre-test	SCAT	Post-test	Pre-test	SCAT
Film	22.75	76.25	40.20	+1.93	+1.35
Non-Film	26.60	78.95	49.35	−1.92	−1.35
Total	24.68	77.60	......	......	......

Adjusted mean for film group:

$$40.20 + (.2064)^{*}(1.93) + (.3430)^{**}(1.35) = 41.06$$

Adjusted mean for non-film group:

$$49.35 - (.2064)^{*}(1.93) - (.3430)^{**}(1.35) = 48.49$$

* b_1 for Within (see Table VI).
** b_2 for Within (see Table VI).

AN EVALUATION OF THE INTRODUCTORY CHEMISTRY COURSE ON FILM BY FACTORIAL DESIGN AND COVARIANCE WITH METHOD AND CAREER PLANS AS THE MAIN VARIABLES

KENNETH E. ANDERSON

Dean, School of Education, University of Kansas, Lawrence, Kansas

FRED S. MONTGOMERY

Director, Bureau of Visual Instruction, University of Kansas, Lawrence, Kansas

AND

DALE P. SCANNELL

Director, Bureau of Educational Research and Service, University of Kansas, Lawrence, Kansas

INTRODUCTION

A PREVIOUS article entitled "An Evaluation of the Introductory Chemistry Course on Film" describes the population and rationale behind the present study.

PROBLEM

The problem was one of testing which method produced superior results in measured achievement during one year of instruction: the conventional method or the film method of instruction. The design of the study was a 2 x 2 factorial type. The factors were the two methods (film or non-film) of instruction and plans of go to college for a *science career* and *non-science career*. Analysis of covariance was introduced in that the pre-test and SCAT scores were held constant. The factorial design employed permitted stratification of the data and the testing of three null hypotheses as follows:

1. Students taught by the film method did not differ in achievement in high school chemistry from the students taught by the non-film method with pre-test and SCAT scores held constant.
2. Students who planned to go to college for a science career did not differ in achievement in high school chemistry from students who planned to go to college for a non-science career with pre-test and SCAT scores held constant.
3. The science career students did not differ in achievement in high school chemistry when taught by the film method and when taught by the non-film method from the non-science career students when taught in the two same ways.

The primary hypothesis was the first and hypotheses two and three help make the first more meaningful than had they not been introduced into the problem. From the standpoint of the efficiency of the factorial design, it can be said that we will have tested one hypothesis regarding interaction and two hypotheses concerning main effects. If the single-factor plan of experiment had been used, the two main hypotheses would have required separate treatments and no information would have been possible concerning the effect of interaction. A simple analysis of covariance approach with four groups (film—science career, film—non-science career, non-film—science career, and non-film—non-science career) would have required six t tests if the F value proved to be significant. Also, the interaction effect would not have been available.

TESTS USED IN THE STUDY

In order to secure necessary data for a statistical test of the three null hypotheses, two tests were administered:

1. The *Anderson Chemistry Test, Form Am,*[1] as a pre-test and post-test at the beginning and

[1] Published by the World Book Company, Yonkers-on-Hudson, New York.

end of the school year. Raw scores were used in the calculations.

2. The SCAT or *School and College Ability Tests.*[2] The SCAT was given at the mid-point of the school year. Total raw scores on the test were used in the calculations.

PROCEDURE AND STATISTICAL ANALYSIS

There were 590 students distributed as follows:

Film method—science career	65
Film method—non-science career	62
Non-film method—science career	190
Non-film method—non-science career	373

Ten students were selected by means of random numbers from each of the four groups and their scores appear in Table I. The three distributions of pre-test, SCAT, and post-test scores did not depart markedly from the normal distribution. Thus, the set of 40 scores in Table I represent random scores from normal populations.

The next step was the calculation of the sums appearing in Table II.

[2] Published by the Cooperative Test Division, Educational Testing Service, Princeton, New Jersey.

TABLE II

SUMS OF SCORES, SUMS OF SCORES SQUARED, AND SUMS OF CROSS-PRODUCTS

Group	Science Career		Non-Science Career	
Film	ΣX	= 268	ΣX	= 213
	ΣX^2	= 8,174	ΣX^2	= 4,693
	ΣY	= 779	ΣY	= 838
	ΣY^2	= 64,207	ΣY^2	= 71,182
	ΣZ	= 512	ΣZ	= 425
	ΣZ^2	= 28,252	ΣZ^2	= 18,455
	ΣXY	= 22,197	ΣXY	= 17,822
	ΣYZ	= 42,326	ΣYZ	= 36,035
	ΣXZ	= 14,708	ΣXZ	= 9,005
Non-Film	ΣX	= 272	ΣX	= 280
	ΣX^2	= 7,746	ΣX^2	= 8,474
	ΣY	= 814	ΣY	= 789
	ΣY^2	= 68,106	ΣY^2	= 67,995
	ΣZ	= 555	ΣZ	= 494
	ΣZ^2	= 31,835	ΣZ^2	= 26,216
	ΣXY	= 22,024	ΣXY	= 21,879
	ΣYZ	= 45,569	ΣYZ	= 40,842
	ΣXZ	= 22,024	ΣXZ	= 13,971

The data in Table II were used to obtain the sums of squares or SS's which appear in Table III. The calculations used to obtain the SS's were the same as those illustrated in the previous article entitled: "An Evaluation of the Introductory Chemistry

TABLE I

SCORES OF FORTY STUDENTS

Group		Science Career			Non-Science Career		
		X*	Y**	Z***	X*	Y**	Z***
Film	1	25	73	48	22	85	43
	2	36	99	73	21	90	52
	3	41	108	68	16	86	38
	4	18	72	52	27	94	44
	5	39	64	43	20	88	44
	6	9	36	20	16	90	53
	7	19	82	51	21	94	44
	8	27	78	62	22	75	32
	9	34	90	54	29	74	39
	10	20	77	41	19	62	36
Non-Film	1	31	89	51	29	75	59
	2	41	81	37	30	68	34
	3	25	84	52	35	16	32
	4	29	50	50	47	107	61
	5	23	83	51	24	74	28
	6	25	105	74	17	91	49
	7	17	80	56	24	77	63
	8	29	76	70	21	95	42
	9	25	93	52	24	97	60
	10	27	73	62	29	89	66

* Raw scores on the pre-test.
** Raw SCAT scores.
*** Raw scores on the post-test.

TABLE III

BASIC DATA TABLE SUMS OF SQUARES

Source of Variation	Σx^2	Σxy	Σy^2	Σyz	Σz^2	Σxz
Method	126.02	—24.85	4.90	—39.20	313.60	198.80
Career	55.22	—39.95	28.90	—125.80	547.60	173.90
Interaction	99.23	—132.30	176.40	—54.60	16.90	40.95
Within	2,129.31	962.60	12,069.80	5,118.60	5,315.00	808.90
Total	2,409.78	765.50	12,280.00	4,899.00	6,193.10	1,222.55
Method plus Within	2,255.33	937.75	12,074.70	5,079.40	5,628.60	1,007.70
Career plus Within	2,184.53	922.65	12,098.70	4,992.80	5,862.60	982.80
Interaction plus Within	2,228.54	830.30	12,246.20	5,064.00	5,331.90	849.85

Course on Film by Factorial Design and Covariance with Method and Sex as the Main Variables."

The sums of squares in the last five rows were used to obtain the regression coefficients which appear in Table IV.

TABLE IV

REGRESSION COEFFICIENTS

	b_1	b_2
Method	.281	.399
Career	.285	.391
Interaction	.233	.398
Within	.195	.409
Total	.388	.375

The adjusted sums of squares appear in Table V. The SS's were divided by the proper degrees of freedom to obtain the mean squares. The mean square for career was the only significant one and indicates that a significant difference in chemistry achievement occurred in favor of the science career students or the non-science career students with pre-test and SCAT scores held constant. Since the F value for method was not significant, no bias was introduced by this factor, nor was it influenced by an interaction between method and career since the F value for interaction was not significant.

Since the mean squares for method and interaction were not significant, the SS's for these were added to the SS for within to secure a new error term. The new SS's appear in Table VI.

The new SS for within appears in Table VII and the problem has now been reduced to ordinary analysis of covariance.

Entering the F table with 1 and 36 degrees of freedom, we note that the F value of 5.58 was significant at the 5 per cent level. Before securing the adjusted means, homogeneity of variances and regression had to be established between the two career groups. F values of 1.27 and 1.04 were secured. Entering the F table with 19 and 19 degrees of freedom, we note that neither F ratio was significant.

TABLE V

ADJUSTED SUMS OF SQUARES

Source of Variation	d.f.	SS	MS	F	Probability
Method	1	255.00	255.00	2.83	$P>.05$
Career	1	566.62	566.62	6.29	$P<.05$
Interaction	1	54.65	54.65	0.61	$P>.05$
Within	34	3,063.76	90.11	....	....
Total	37	3,129.34	......	....	....

TABLE VI

SUMS OF SQUARES FOR WITHIN PLUS METHOD INTERACTION

Source of Variation	Σx^2	Σxy	Σy^2	Σyz	Σz^2	Σxz
Within	2,354.56	805.45	12,251.10	5,024.80	5,645.50	1,048.65
	$b_1 = .312$				$b_2 = .390$	

Adjusted SS = 3,360.55

TABLE VII

ANALYSIS OF COVARIANCE

Source of Variation	d.f.	SS	MS	F
Within	36	3,360.55	93.35	....
Between	1	521.08	521.08	5.58
Total	37	3,881.63	......	$P<.05$

Which group achieved the most, the science career students or the non-science career students? In order to answer this, the adjusted means were calculated. These were 53.35 and 45.95 respectively for the science career and non-science career students.

CONCLUSION

We were now in the position to draw the following conclusions on the basis of the data obtained:

1. The film and non-film groups achieved the same with pre-test and SCAT scores held constant. This was our primary hypothesis.
2. The science career students achieved significantly more than the non-science career students with pre-test and SCAT scores held constant, since the F was significant at the 5 per cent level and the adjusted means were 53.35 and 45.95 respectively. Since the F values for method and interaction were not significant, the conclusion was not biased by the factor of method nor influenced by interaction between method and career. Since the F value for career was significant, control of this factor by stratification was justified.

It is planned to introduce factors other than career into additional factorial designs. In this way, it will be possible to vary all the essential conditions simultaneously rather than one at a time. The results, therefore, will have wider applicability than do single experiments.

MUSIC AND RADIOS: A TOOL IN CHEMISTRY LABORATORIES

MALCOLM H. FILSON
Central Michigan College, Mt. Pleasant, Michigan

TAKING a leaf from industry, where employers have found music can play an important role in mass production operations, the theory and plan has been applied to the ordinary undergraduate chemistry laboratories at Central Michigan College with remarkable and certainly noticeable results.

For years it has been common practice to place radios and other sources of music in plants where monotonous operations of mass production are a regular order. Many reasons have been advanced by psychologists, engineers and employers, that music soothes the nerves, causes relaxation and gives the operator a restful feeling, thereby helping him to continue work for long hours without undue mistakes, repeats, or injuries.

Long assembly lines, where each operation adds a unit, or in large plants where operators perform tedious tasks for long hours, with only short rest periods, have been found to tire the operator more, when music is not available, than when it is as part of the plant routine.

Following this practice, a master radio was installed in the main office of the Department of Physics and Chemistry at Central Michigan College two years ago, with remote speakers in the various chemistry laboratories.

Each speaker in the respective labs has a volume control within reach of the instructor or student. Programs of music and instructional information are selected and the master radio operated during laboratory working periods.

When one instructor wishes to lecture, he can operate his speaker without stopping or interfering with the programs being 'piped' to other labs.

It has been found that students, who previously would 'cut' their labs for short periods to listen to programs of interest, or to hear music while resting, no longer leave the labs, but continue with their routine work or research.

It was even noticed that less 'smoke' or 'cigarette' breaks are taken by the students.

Students who were taking current events and related courses as well as chemistry, would request news broadcasts, Presidential and other major speeches along with sporting events also are frequently requested and heard.

It is noticeable that more work is accomplished by the students in a shorter period of time. The quality of work also does not suffer and if anything is better.

Next year radios will be installed in physics laboratories, and results noted. It also is recommended that high school instructors might try this type of educational tool in their laboratories and laboratory instruction, especially if lab periods run either two or three hours, without rest periods.

The author suggests that biology laboratories might employ this technique for possible greater efficiency, and it certainly will give the science student and prospective scientist a more pleasant approach to laboratory course work, which have a reputation of being tiresome and laborious.

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